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Hilo Coast Processing Co, Pepeekeo, Hawaii

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ELECTROSTATIC CANE PROCESSING SYSTEM: PROTOTYPE PHASE

by

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S-802420

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KEY WORDS AND DOCUMENT ANALYSIS

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Justification for NTIS Distribution

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As presented, this project lacks an adequate data base to allow a thorough engineering analysis of the various control systems. As a result, we recommend that the report not be published as part of EPA's ORD publication series. However, it does present in a narrative form many of the problems that can occur when demonstration scale systems are undertaken without adequate pilot plant evaluation. This case history of poor industrial planning, although not acceptable for EPA publication, should be made available for public dissemination. The information and ideas contained in the report should not be removed from public use by our inaction or by an "UNPUBLISHED ONLY" decision.

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This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes a method for the disposal of soil-laden wash water from the cleaning of sugar cane harvested mechanically in a high rainfall semi-tropical area. The results should be useful to any agricultural enterprise faced with the problem of disposing of several hundred tons of soil per day together with several million gallons of water per day. The report is primarily a description of uncomplicated applied research, of value perhaps to those seeking information on uncommon methods for land disposal of agricultural wastewater.

For further information, contact the Food and Wood Products Branch of IERL-Cincinnati.

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ABSTRACT

The overall objective of this project was to demonstrate a systems environmental management approach, from field to final product, for the processing of raw cane sugar. Specific sub-systems which were to be developed and demonstrated as part of this systems approach were: (a) harvester-cleaner-transporter, (b) dry cane cleaner, (c) juice washing of dry cleaned cane, (d) soil and wastewater disposal, (e) cane trash wet cleaner, and (f) fibrous wastes burned for the generation of commercial electrical power.

While the systems approach is a viable one for waste reduction, it suffers from the weakness that if one sub-system fails to operate as expected it directly affects the successful operation of all or part of the total system. In this study the failure of the harvester-cleaner-transport system led directly to the failure of the juice washing and trash cleaning concepts. In addition, it hampered the successful operation of all the other sub-systems.

Failure of the harvester-cleaner-transport system led to modifying the dry cleaner so that it could be used as a wet cleaner. Water used in this cleaner was screened and recycled back to the cleaner, ultimately being rescreened and disposed of on land via infiltration trenches. Generation of commercial power from fibrous wastes was the most successful aspect of the study. However, oil was necessary as a supplemental fuel due to inadequate supplies of bagasse.

This report was submitted in fulfillment of EPA Grant No. S-802420 by Hilo Coast Processing Company under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 31, 1973 to September 30, 1976.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

BTU	==British thermal units
BL	==Buggy loader
CMH	==Cane-materials-handling
CWT	==clean water trenches
DO	==dissolved oxygen
gpm	==gallons per minute
g	==grams
HCT	==Harvester-cleaner-transport
HELCO	==Hawaii Electric Light Company
HCPC	==Hilo Coast Processing Company
in/hr	==inches per hour
MVA	==maximum volume available
MWH	==megawatt hours
mgd	==million gallons per day
ppm	==parts per million
psi	==pounds per square inch
PUC	==Pick-up-cleaner
PUCT	==Pick-up-cleaner-transport
PUT	==Pick-up-transport
SAR	==Sodium adsorption ratio
ST	==settling trenches
T	==Tons
TD	==To date

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SECTION I

INTRODUCTION

The object of this grant, which is, in part, a continuation of EPA Grant S-801221, is to develop environmentally sound systems for sugar cane harvesting and processing, wastewater reuse and reduction, and solid waste recovery. These systems were to result in major reductions in solid and liquid waste, provide more efficient recovery of raw sugar and provide a supply of electrical energy. These results were addressed from a total systems approach. This grant is for the development and demonstration of a prototype operation.

This project was conducted by the Hilo Coast Processing Company of Pepeekeo, Hawaii. Studies were conducted during the 1973-1976 campaigns at the Company's member plantations and at their Pepeekeo and Papaikou sugar cane mills.

The prototype phase is composed of several units, or subsystems, which are:

1. Harvester-Cleaner-Transporter
2. Soil and Wastewater Disposal
3. Juice Washing of Dry Cleaned Cane
4. Dry Cane Cleaner
5. Fibrous Waste Power Generation
6. Cane Trash Wet Cleaner

Previous cane hauling consisted of a "brute force" approach to removing the cane from the field and getting it to the mill, with little or no regard for soil and waste reduction. This harvesting involved V-cutting the cane, and then raking and/or grabbing it with a crane to place it into an open cane truck. It was then taken to the mill where trash and soil were removed and dumped directly into the ocean.

Several subsystems of this grant were developed to improve on the above situation. They are:

1. Harvester-Cleaner-Transporter
2. Dry Cane Cleaner
3. Juice Washing of Dry Cleaned Cane

The Harvester-Cleaner-Transporter system consists of new harvesting machines, methods and trucks designed specifically to minimize the amount of trash and soil brought from the field to the mill.

The Dry Cane Cleaner, though not a success when operating on a totally dry basis, has proven quite successful in reducing the amount of dirty water generated and all but eliminated, in conjunction with the other subsystems (see below), the disposal of trash and dirty water into the ocean.

A further effort to minimize sugar loss and water use by using cane juice instead of water for the washing of dirty cars from the field has, so far, proved unsuccessful.

In the areas of waste management: (1) Soil and Wastewater Disposal, (2) Fribrous Waste Power Generation, and (3) Cane Trash Wet Cleaner, were three subsystems investigated to improve the former practice mentioned above of discarding trash, dirty water and bagasse into the ocean.

Screens were installed to remove trash and large soil particles from the cleaning water which was found necessary to introduce into the "dry" cleaner in order to improve its cleaning ability. Pumps were also installed for water recirculation so that the water could be reused after screening, thus cutting down on the total amount of water needed. The soil and trash removed by the screens is currently being used as landfill. So far no viable way of cleaning the trash for use in energy production (burning) has yet been devised.

The dirty water, after final screening, is disposed upon the land into a system of trenches, thus eliminating any dirty water disposal into the ocean.

Bagasse is now used for power generation (20,000 KW generating facility), with the plantation producing about 20% of the island's electrical needs.

SECTION 9

CONCLUSIONS

While the systems approach to waste reduction is a viable approach, it suffers the weakness that all or part of the total system may not operate properly should one part fail to function. And since most systems development and testing had to be done on a production (field) basis, rather than on a laboratory scale, the risks inherent in this approach can be great.

The harvester-cleaner-transporter (HCT) system is an example of a subsystem which could only be evaluated fully on a full-scale field basis and upon which other systems were dependent. It was found that unforeseen cane losses occurred when all parts of the (HCT) were in operation (i.e., fans, rollers and knives). In order to minimize this loss, the knives had to be shut off, which resulted in the fans having to be shut off, and a concurrent increase in trash and soil over that resulting from all parts operating. This resulted in dirtier cane than anticipated arriving at the mill which in turn led to the omittal of the juice washing of cane because it was too dirty for the juice to handle.

The dirtier than expected cane also resulted in trash too dirty to wash and therefore excluded its use as fuel and also led to the need to add water washing to the dry cleaner in order to improve the quality of the cleaned cane.

As the total system is still evolving, it is difficult to estimate what final loadings will be. Currently less than 20% of the cane is harvested by these advanced machines. As more operators are trained, and more machines arrive, this percentage could go as high as 50% but will vary considerably with rainfall, both as to the percent of cane harvested by improved machines and their efficiency of soil removal.

Currently, about 1200 gpm of water are used and disposed of at the Papaikou cleaning plant. It is planned that this will soon be reduced to 700 gpm of water as recirculation plans for water at the cleaning plant progress and the amount of harvesting by the new machinery increases.

Since the amount of trash and soil brought to the mill resulted in greater than expected loads, this led to increased demands on the soil and wastewater disposal systems. These systems, however, are readily expandable to meet the increased demand on them and will be able to handle the additional load satisfactorily, though at an increased cost.

The use of cane fiber residue for power generation has proven to be quite successful, with over 20% of the island's electrical needs now being supplied by the Hilo Coast Processing Company.

Before the advent of this grant and the inception of the Cane-Materials-Handling (CMH) concept, sugar factories along the Hilo and Hamakua Coast had little or no environmental waste management programs. Thus, progress accomplished during this grant represents most of that accomplished in the areas of water and solid waste management. The factory has essentially gone from direct disposal of dirty water and trash, with no pretreatment, directly into the ocean, to the capability of a minimal solid discharge which is acceptable to environmental constraints and with no discharge of cane trash.

SECTION 9

RECOMMENDATIONS

Although progress has been achieved in the disposal of sugar cane waste fiber and cane wash water there are areas which warrant further investigation.

The Cane Materials Handling (CMH) system has potential. However, until the development of an adequate ground sensor for the ground knives is completed, the single pass harvesting concept, with its concurrent soil and trash reduction, remains a thing for the future.

At the mill, more-detailed information is needed about the cleaning plant efficiencies and losses from various sections. Further improvement of the water recirculation should also be studied during such investigations.

Examination of silt deposited at the discharge end of the trenches at some land containment test sites reveals probable anaerobic decomposition of organic matter with a temporary loss of soil fertility. Evaluation of this effect could be helpful on a long-range basis even though no permanent loss of fertility has been observed to date.

Land containment of soil-bearing waste waters should be considered as a viable alternative when the solids loading of the waste water is extremely high.

SECTION 4

HARVESTER-CLEANER-TRANSPORTER

Until the 1960's, sugar cane in Hawaii was harvested by hand. This process consisted of both cutting (harvesting) and removal of trash (i.e. leaf and other waste material) in the field and transportation of the cane stalks via water flumes to the mill, which was situated at a lower elevation along the coast. Thus almost no trash or soil was brought to the mill, and the only pollutant resulting from the cane was an occasional surplus of any bagasse (fibrous material composing the stalks which is left after sugar juice removal) not used for steam generation.

With the advent of mechanical harvesting, the removal of trash and soil in the field was no longer done, and this material was then transported to the mill along with the cane. It was necessary to remove the material at the mill via "cane cleaning plants," rather than leave it in the field as had been done previously with hand harvesting. The cleaning plants consisted of machinery to strip the trash from the cane, and water baths to remove the adhering soil. The dirty water and trash were then dumped into the ocean.

The conventional mechanical harvesting (before the advent of equipment evaluated in this and the previous grant) consisted of a V-cutter (Figure 1) which knocks the cane down into rows (windrows), a buggy which carried the cane to the roadside along the field, and a crane which then loads the cane into trucks for transport to the mill. During this sequence the cane is pushed into and mixed with the soil when V-cut, mixed again with it when picked up for transport to roadside and once again intermingled with the soil when loaded from roadside (Figure 2) into the cane truck.

The new harvester-cleaner-transport (HCT) system, also known as "Cane-Materials-Handling" (CMH) system, was designed with three concepts in mind: 1) to minimize soil-cane contact, 2) to remove the majority of soil and trash in the field rather than at the mill (cleaning plant), and 3) to provide more efficient transport of cane from the field to the mill.

The HCT system consists of three main areas: picking up cane, transporting cane, and cleaning cane. The buggy-loader (BL) (Figure 3) is similar to the buggy in that its purpose is transport of cane from the field. It differs in that not only can it be loaded by a crane but also by the pick-up-cleaner (see below). In addition it can unload its cane directly into a truck or into a high roadside pile, by-grading (see below).

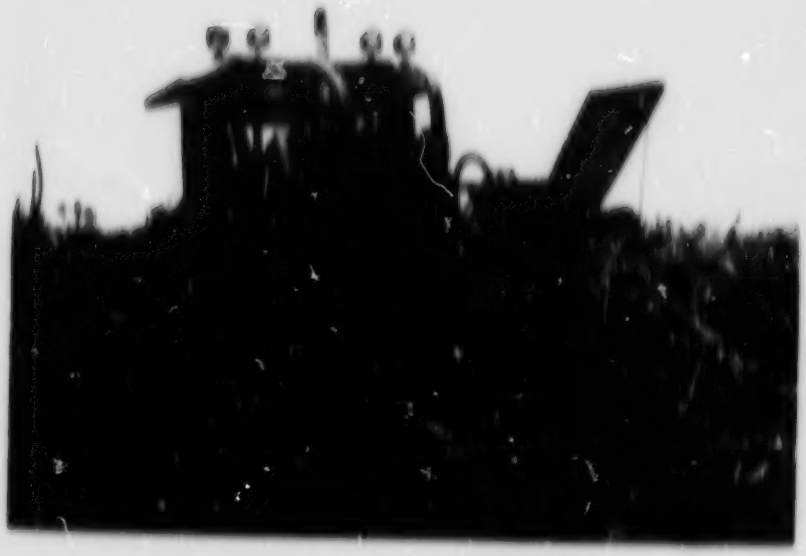


Figure 1. V-cutter.

Figure 2. Cane being loaded at roadside by crane into truck.

Figure 3. Buggy-loader loading cane directly into truck.

The pick-up-transport (PUT) (Figure 4) is designed to minimize soil-cane interaction by providing an alternate and cleaner method of picking up windrowed cane than via a crane. However, it is not capable of a high dump for hy-grading.

The pick-up-cleaner (PUC) (also called a pick-up-cleaner-transport (PUCT)) combines the advantages of the buggy-loader and PUT. In addition, it is also capable of cleaning the cane of trash and soil in the field (Figure 5). As usually operated, the PUC will pick up the windrowed cane, clean it, and then transfer it to a buggy-loader which then transfers it directly to the cane truck for hauling to the mill.

A further step, currently under development is what is known as a "single pass" PUC, or a PUC equipped with ground knives. In this case, a PUC is equipped with ground knives for cutting the cane first. It then picks it up, cleans it, and transports it to either a BL or directly to roadside where it is then dumped directly into a cane truck. This method limits the cane-soil interaction to just the harvesting step and if the cane is caught and brought into the PUC before it falls to the ground after being cut, this single contact of the cane with the ground is held to a minimal amount.

A fully equipped PUC would handle the cane in the following manner: First, the cane would be cut with the ground knives, it would then be picked up and chopped into short lengths. It would then fall onto special rolls (Figure 6) for removal of soil and dirt. Suction exhaust fans (Figure 7) would then extract trash which had been cut from the stalks during the chopping process. Thus, after passing through the PUC, the cane would have had most of the soil and trash removed. It could then be loaded directly into a

Figure 4. Pick-up-transport.

Figure 5. Pick-up-cleaner.

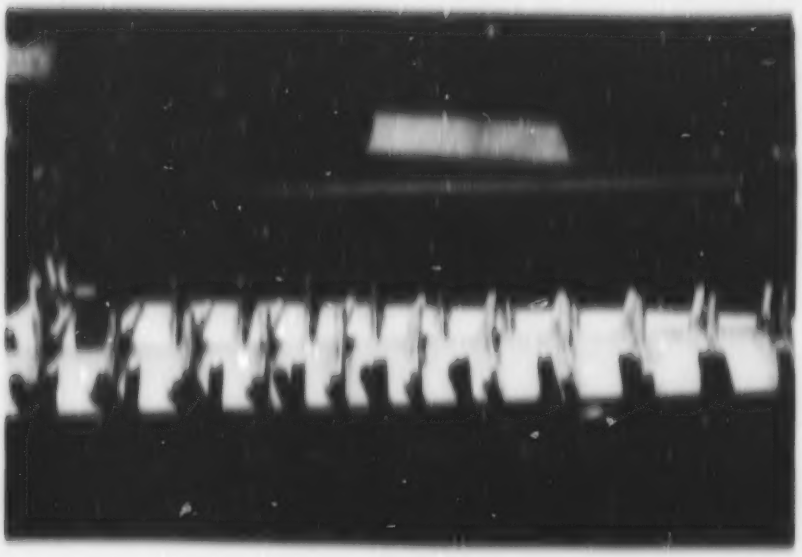


Figure 6. Rolls in pick-up-cleaner.

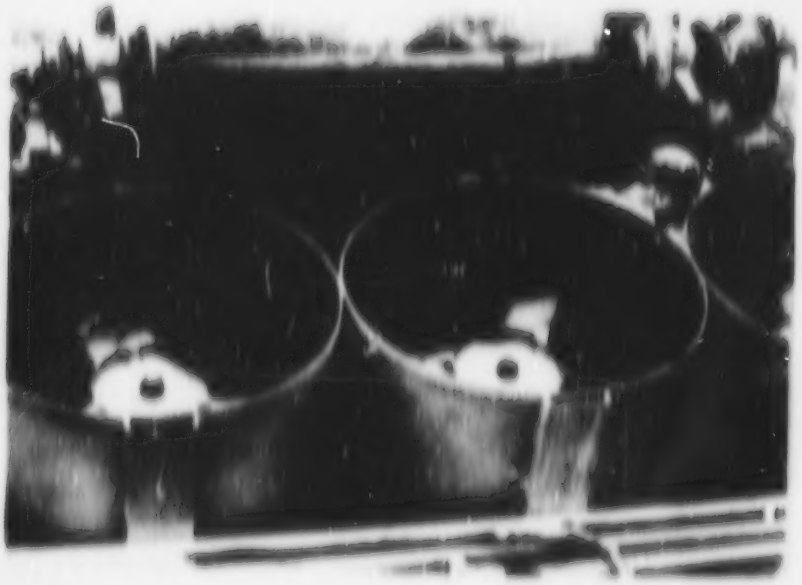


Figure 7. Section exhaust fans on pick-up-cleaner.

closed truck (Figure 8), or first into a buggy-loader for transport to a closed truck, and then taken directly to the mill. At the mill it would go through a final cleaning (dry cleaner) and then into the factory for processing.

The PUC has been discussed thoroughly in the first grant report, so our discussion here will be limited to developments which have occurred since.

Ground Knives

Shortly after installation of the ground knives, it was discovered that proper elevation control could not be maintained. Thus, the knives would either cut too high, leaving the cane in the field; or too low, harvesting soil along with the cane. To date, this problem (development of an adequate sensor for ground level) has not been solved.

The same problem was encountered earlier with the attempted development of ground knives for the V-cutter.

Current Operational Status of CMH

Currently, the PUC is operating in the long cane mode. This means that the chopper knives (Figure 9) have been removed. The reason for the removal is the loss of sugar due to use of the chopper knives.

Table 1 shows results of tests of conventional vs. CMH harvesting, indicating that the conventional harvesting exhibits about a 10% increase in sugar harvested over the CMH method. To date, the exact reason for the increase is not known, though it is thought to be a combination of physical cane loss within the CMH system (in the field, falling out during transport, at the dry cleaner) and a sugar loss from wet washing the cane because of the enhanced surface area of exposed ends of cane pieces. The PUC, therefore, is currently being used without the chopper knives.

TABLE 1: SUGAR PRODUCTION OF CMH AND CONVENTIONAL HARVESTING

	CMH	Conventional
Tons Sugar Per Acre* (Test 1)	11.45	12.61
Tons Sugar Per Acre* (Test 2)	11.27	10.37
Average	11.36	12.49

*Measured via mixed juice

Figure 8. Closed cane truck.

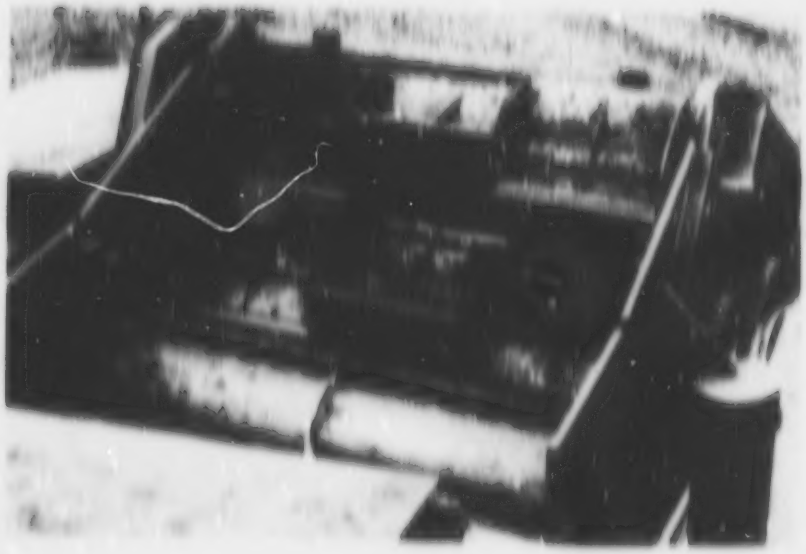


Figure 9. Chopper knives of pick-up-cleaner.

Using the PUC without the chopper knives also means that it must be used without the blowers. This is because the blowers are dependent upon the trash (i.e. leaves, etc.) being first separated from the stalks by the knives so that it can be removed by the blowers. This is unfortunate because a considerable portion of the soil is associated with the trash, especially in wet fields. Table 9 lists some advantages of blower use, as do Figures 10 and 11; however, the advantages do not offset the sugar loss caused by use of the short cane mode.

TABLE 9: PUC: NO BLOWERS vs. BLOWERS

	No Blowers	Blowers
Net Cane (%)	63.9	71.6
Density (lb/ft^3)	16.6	19.0
Trash (%)	19.9	11.3
Soil in Cane (%)	33.5	25.14
Soil Moisture (%)	61.84	64.39
Dry Soil	12.11	8.85
Bin Capacity (Tons)	6.63	7.36
Production Rate (TC/hr)	57.8	61.4
Buggy Range (ft)	466.	642.
Trucking (%)	114.	100.

Enclosed Trucks

The enclosed, side-dumping trucks (Figures 8 and 12) were designed specifically to be part of the CMH system and to utilize the special unloader installed at Papaikou factory. The purpose of this design was to eliminate trash and litter during transport from the field to the factory. As can be seen in Table 9, a higher packing density was also achieved using the short cane in these trucks (short cane tended to fall out of conventional trucks through the gaps in the chains comprising their sides and bottoms).

With the failure of the CMH system to date, these trucks are no longer being utilized, as they are not suitable for the transport of long cane.

Ash Measurement

In order to measure the amount of entrained soil in the cane brought to the factory, an ashing procedure was developed. This is based upon the theory that organic matter (e.g. cane) leaves little residue on ashing (500°C) while inorganic matter (e.g. soil) leaves considerably more.

Trials on very clean sugar cane showed that when ashed, 0.4% of the original weight of cane remained (note: all original weights are constant oven dried (100° - 110°C) weight).

Soil samples were then taken of the three soil types encountered at Hilo Coast Processing Company (HCPC) (Kaiwiki, Hilo and Ainaka), dried at

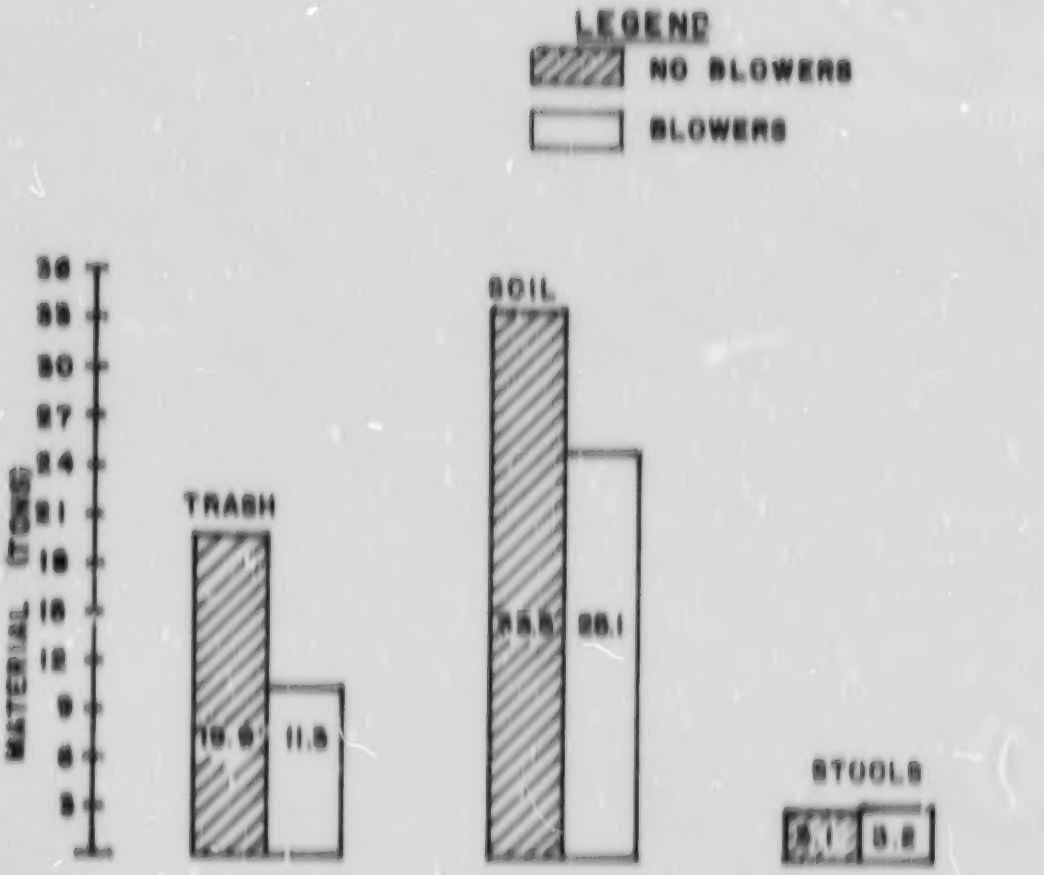
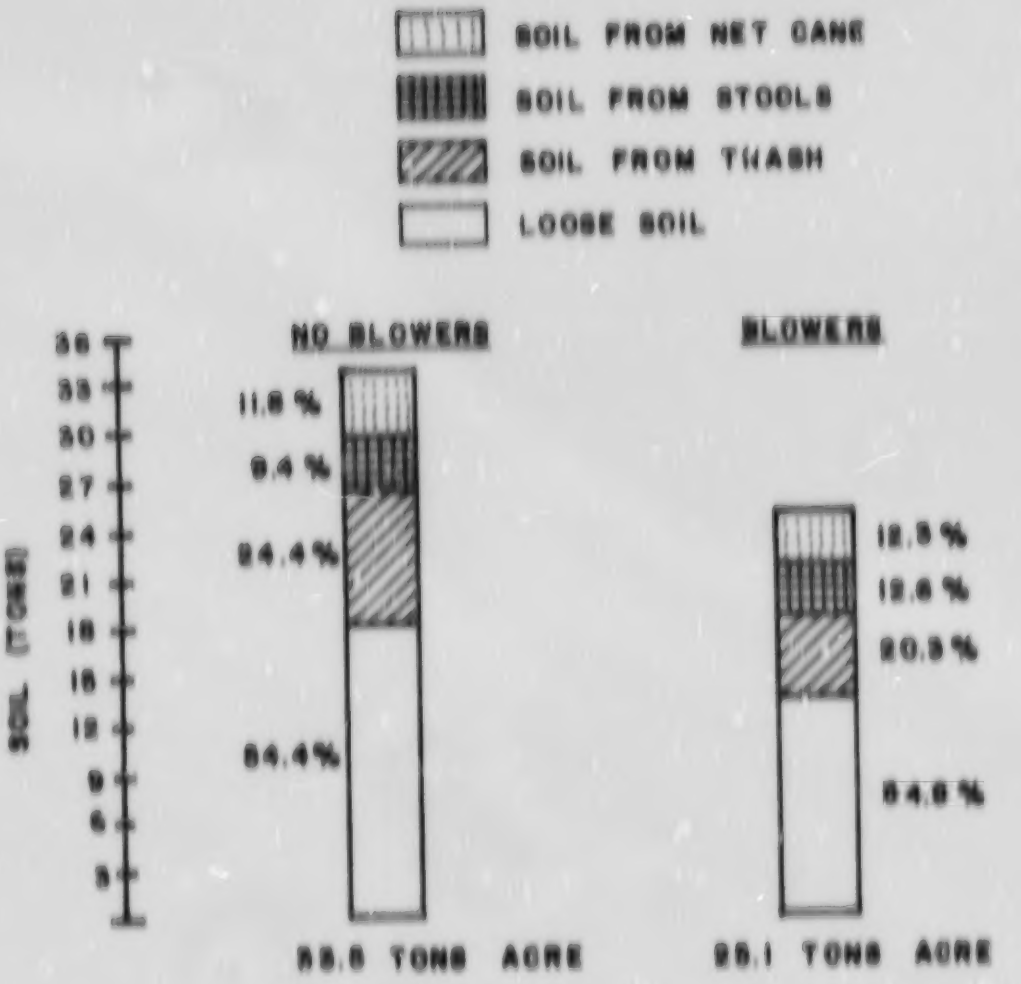


Figure 10. Blower vs. no blower comparison.



NOTE: BASED ON 100 TON NET CANE PER ACRE

Figure 11. Percent breakdown-soil.

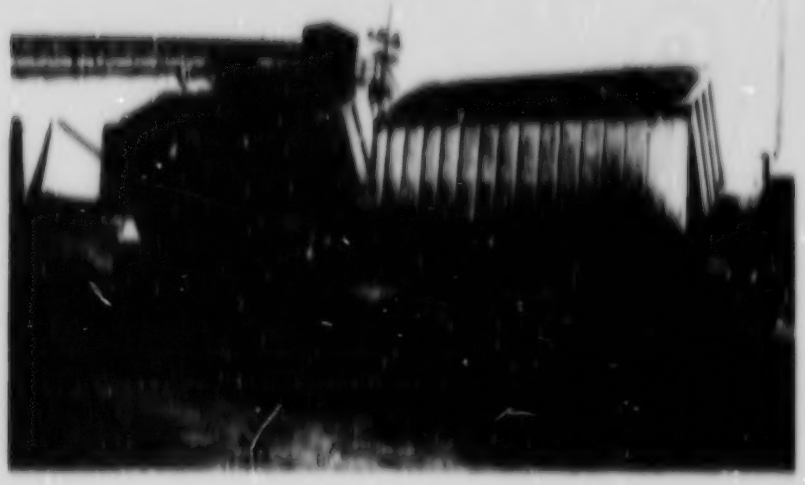


Figure 12. Enclosed truck dumping short cane at Papaikou factory.

100° - 110°C, and ashed at 500°C. The raw data is given in Appendix A. It was found that after ashing, about 73.5% of the weight remained. Thus, given an ash weight, one could then back calculate the amount of soil present reasonably well by use of a soil/ash ratio. Table 3 shows the results of the sampling program. Formula (1) would then be used to calculate the

(1) (ash weight) x 1.37 = dry soil weight

amount of soil in a cane load.

TABLE 3: SOIL/ASH FOR HCPC SOIL TYPES

	Total	Soil Type Kaiwiki	Hilo	Akaka
Number of samples	43	29	11	3
Mean value	1.36	1.35	1.37	1.37
Standard deviation	0.065	0.074	0.034	0.070

An attempt was made to sample incoming cane to Papaikou, chop it with an ensilage chopper, and then to ash it. It was hoped that a comparison of CMH and conventional harvesting ash contents could be made. However, since there was no core sampler at Papaikou, sample selection and preparation was not adequate. For example: nine short cane samples were taken, resulting in an average ash of 16.1% with a standard deviation of 10.5%. With such a high standard deviation, it was decided that the data were inadequate and not worth the effort expended.

A core sampler was located at Pepeekeo; however, as most of the CMH cane during the time of this study was going to Pe[illegible]aikou it was not often used.

Records are available from the Pepeekeo core sampler for both CMH and conventional harvesting done prior to this study (see sample data sheet, Table 4). This data was used, along with rain gauge data, to attempt to correlate harvesting with rainfall. Unfortunately, a simple linear relationship between rainfall and ash (soil) content does not seem to exist (Figure 13). Actually, this is not surprising, since harvest truck loads from a given field can have anything from top of pile cane with a very low ash content, to liliko which was dragged through the soil for hundreds of feet. Other variables such as ability of the V-cutter operator, crane operator, slope of field (i.e. how fast and well it drains from a rain), etc. also contribute to the large spread in the data points.

The "adjusted" rainfall used in Figure 13 is an empirical relationship developed to take into consideration previous rainfall as well as rainfall for the day of harvest.

Hy-Grading

Current harvesting procedures utilize the concept of hy-grading. Hy-grading is the system whereby harvested cane is deposited along the side of the road in very high piles. In this way, the amount of cane in contact with the soil, before being loaded into a truck by crane, is minimized. In fact, after the top part of the pile is loaded, new cane is then piled on top of the old "bottom of pile," the top is then loaded again, etc. In this way, the bottom is reused several times, thus further minimizing the amount of cane in actual contact with the ground. The rationale behind this is that when the crane picks up the bottom of the pile it is more liable to pick up soil from the ground and soil which has fallen down from higher up in the pile. Thus minimizing this bottom of pile loading can cut down considerably on soil transported along with the cane. Results for several hy-grading tests are given in Table 5.

Currently, there are a limited number of operators available to run the PUCs. As the number of operators and PUCs increases, the percentage of cane harvested by PUC will increase from the approximately 20% currently being harvested by PUC to our estimated 70%. The remaining 30% will have to be harvested by conventional means due to terrain limitations. Hy-grading will be utilized throughout.

TABLE 4. SAMPLE ASH DATA SHEET

Factory Summary - Week Ending 4/12/75

Wainaku (Long Cane)

Day	Tons Gross Material	% Ash	Tons Ash	Unacct'd T. G/cane
1	.00	.00	.00	
2	.00	.00	.00	
3	.00	.00	.00	
4	.00	.00	.00	
5	.00	.00	.00	
6	.00	.00	.00	
7	.00	.00	.00	
Wk	.00	.00	.00	.00
TD	156485.06	9.72	15213.09	5042.09

Pepeekeo (Long Cane)

1	2312.47	7.58	175.19	
2	2670.80	8.97	239.60	
3	2690.13	9.03	242.86	
4	2374.69	9.69	230.15	
5	2958.67	9.52	281.73	424.86
6	2794.59	9.57	267.41	
7	752.16	10.68	80.34	28.41
Wk	16556.51	9.18	1519.17	453.27
TD	244325.63	8.83	21546.89	2291.06

Pepeekeo (CMH Cane)

1	.00	.00	.00	
2	487.14	9.90	48.21	
3	542.14	8.16	44.25	
4	199.86	8.41	16.81	69.83
5	8.52	8.92	.76	
6	429.10	7.05	30.24	
7	.32	.00	.00	
Wk	1666.76	8.42	140.27	69.83
TD	15887.16	6.46	1026.75	498.09

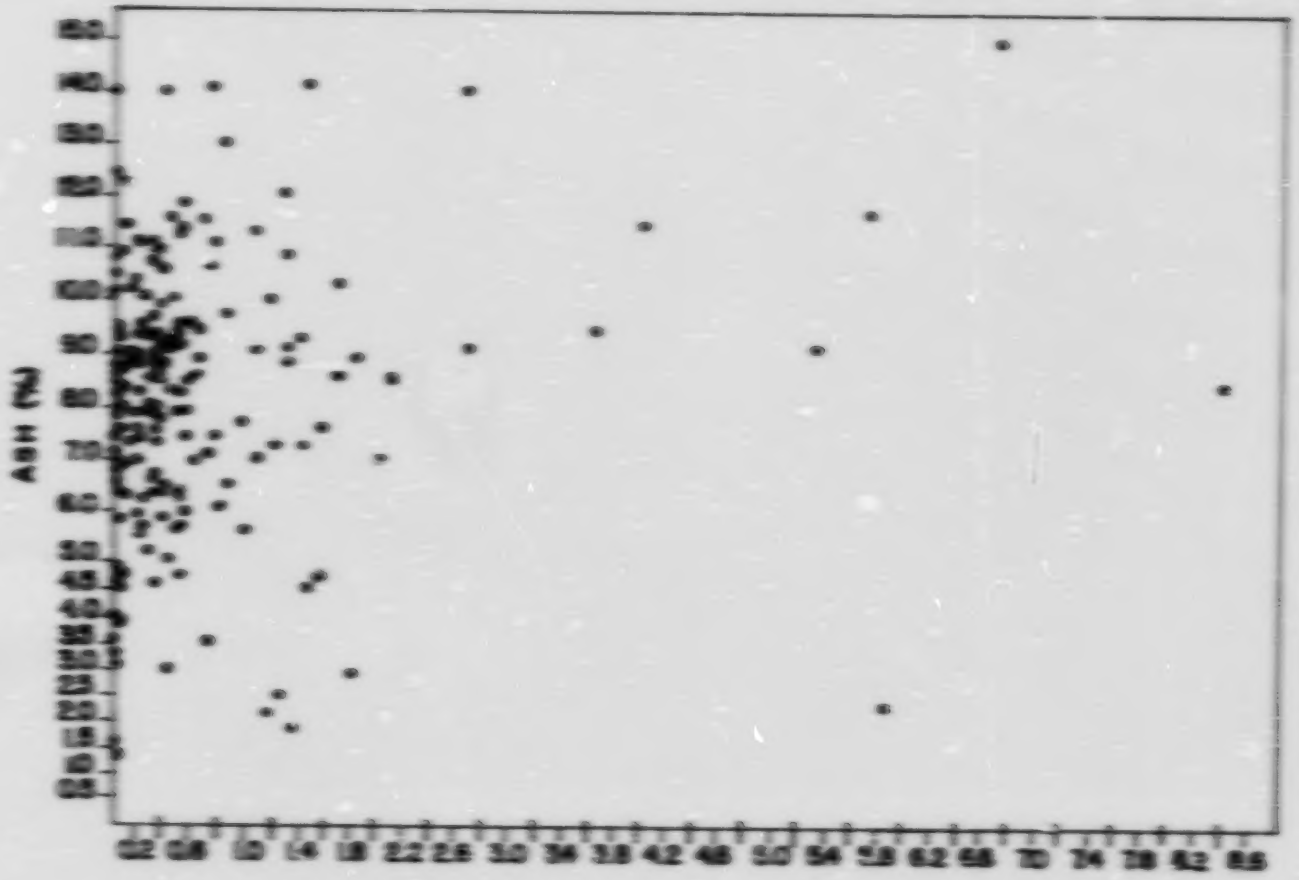


Figure 13. Rainfall vs. ash.

TABLE 5. HY-GRADE TEST DATA

	Date	% Ash	% Pol(sucrose)
Hy-Grade*	11-05-75	13.7	
	3-21-75	6.21	8.0
	3-11-75	8.8	5.4
Average		9.57	6.7
Lo-Grade*	11-05-75	7.61	
	11-05-75	8.0	
	3-21-75	9.64	6.8
	3-11-75	15.34	1.5
Average		10.15	4.15
Liliko	3-21-75	17.81	0.93
	3-11-75	23.56	0.4
Average		20.69	0.67

*Hy-Grade is top of pile; Lo-Grade is bottom of pile.

SECTION 5

LAND CONTAINMENT

In February 1975 new interim final guidelines were announced for discharging material into the ocean. Meeting these guidelines, which were four times as stringent as previously proposed, would have required expenditures of 12 to 17 million dollars for construction of primary treatment facilities. Furthermore, these facilities would have to be designed to handle peak loads which may only occur 10% of the time (Figure 14). An alternate plan of land containment and disposal was then considered (this plan had originally been ruled as too expensive before publication of the interim final guidelines).

Disposal of wastewater on land is dependent on the infiltration rate of the soil. (Infiltration is the process of water soaking into the ground. It is not the same as percolation, which is the movement of water through the soil profile.) This infiltration rate is not constant but is a function of soil type and will also change during a rainfall as the raindrop impact changes the soil surface. It eventually reaches a stable minimum.

Infiltration rates vary widely throughout the state, with values ranging from over 40 in/hr down to 0.1 in/hr. Although just north of HCPC infiltration rates of 5.4 in/hr have been measured for Honokaa soils, measurements made at HCPC indicate infiltration rates of 0.7 in/hr. (Table 6). This number was computed by formula 2.

$$(2) \qquad \frac{\text{(Simulated Rainfall - Runoff)}}{\text{Time}} = \text{Infiltration Rate}$$

TABLE 6.* INFILTRATION TEST DATA

Soil Condition	Slope(%)	Location	Soil Series	Infiltration in/Hr
Dry	8.8	Papaikou	Hilo	0.7
Wet	8.3	Papaikou	Hilo	0.5
Dry	9.8	Papaikou	Hilo	1.0
Wet	9.8	Papaikou	Hilo	0.7
Dry	8.3	Papaikou	Hilo	0.6
Dry	8.4	Papaikou	Hilo	0.4

*From Hawaii Agriculture Experiment Station Research Bulletin 181, May 1975

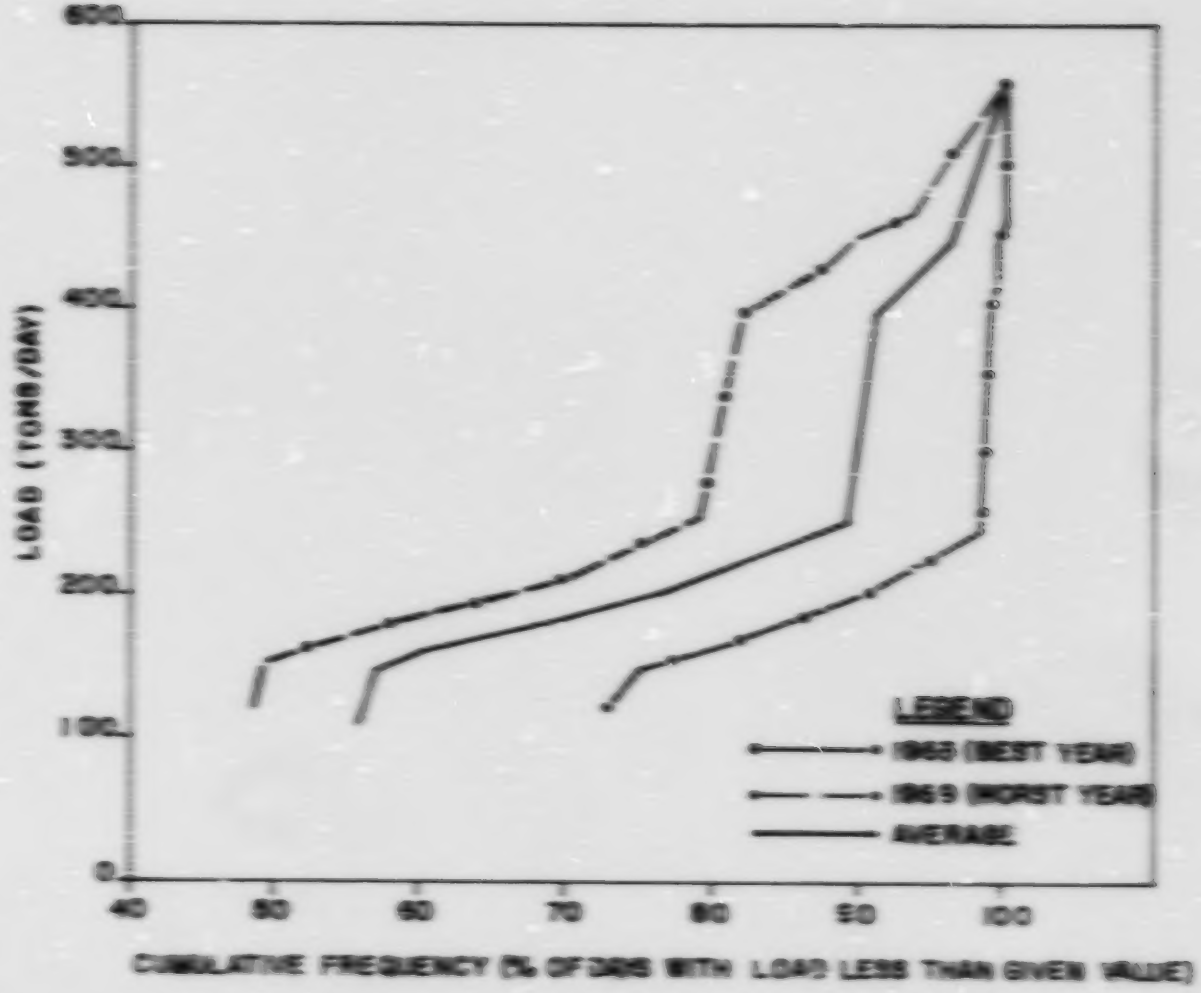


Figure 3A. Cumulative frequency of mill loads to wastewater treatment plant.

It should be noted, however, that infiltration rates can vary considerably depending upon the slope of terrain, history of the soil being tested (e.g. past crop cover and method of plowing) and the type of rainfall with respect to drop size, intensity and frequency.

Along with infiltration rate is the effect the solids in the wastewater will have on sealing the micropores of the soil, thus decreasing the infiltration rate considerably as the silt depth builds up. This was an important concern which received considerable effort in this study.

One of the first questions which needed answering was whether cane could still be grown and harvested on land designated as wastewater disposal land. Past experience at other plantations using discharge water from cleaning plants for irrigation water had produced poor quality cane. However, since our purpose was not the conservation of water but the disposition of it, this previous experience was not necessarily directly applicable to the current problem.

Test Site #1

A test site of approximately one-fourth acre (Figure 15) was chosen. On it was growing cane approximately four months old. A piping system was set up to supply effluent water from the dry cleaner to this area (Figures 16 and 17). Furrows were then plowed between cane rows and a series of flumes were installed for water distribution from the pipe to the land.

The distribution was accomplished by first having the water enter a headbox (Figure 18), it then entered a flume system from which the water could be tapped off to the various furrows. Parshall measuring flumes (Figure 19) were placed at the beginning of all rows and the end of several. In this manner, total water use could be monitored.

Figure 20 shows the test site. The cane at most of the test was about four and one-half feet high. Parshall measuring flumes with three inch throats (Figure 21) were used in all tests unless otherwise stated. Tensiometers for measurement of soil moisture (Figure 22) were also located at test site #1. They were located both in the furrows and on the ridges between them. A reference site was also set up about twenty feet from test site #1. Tensiometer depths at test site #1 were six inches and eighteen inches. Figure 23 shows typical furrow cross-sections. Table 7 gives further information on the test site.

Table 8 shows raw data from test site #1 during one of the first runs.

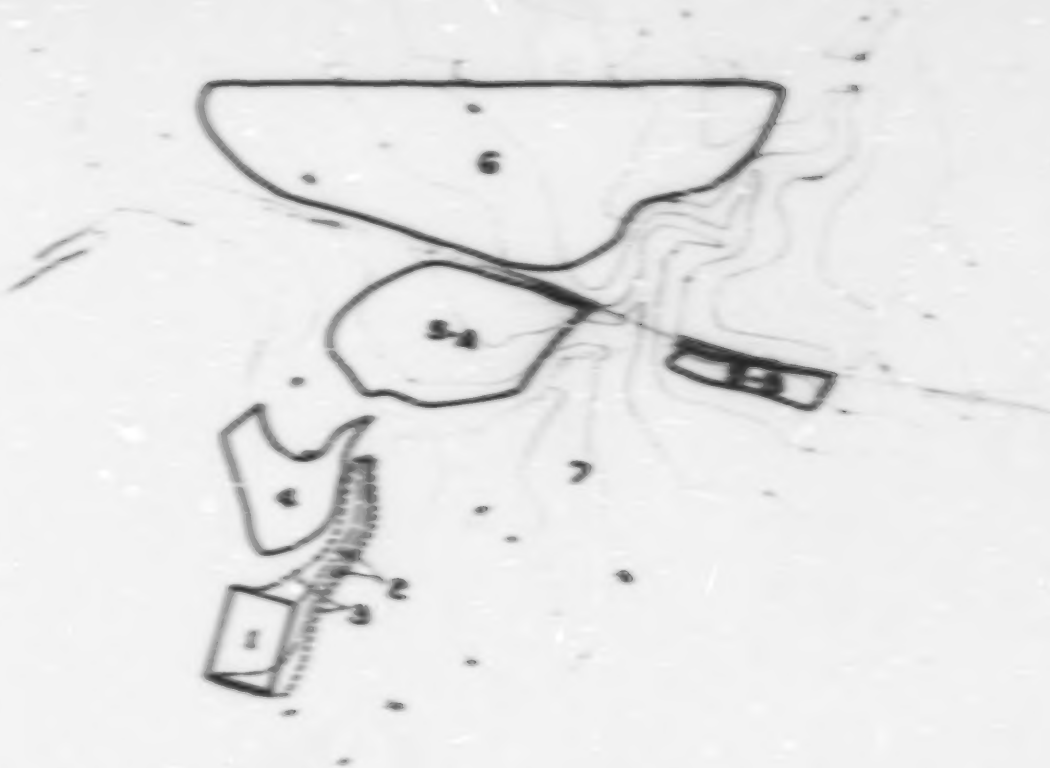


Figure 15. Test site area.

Figure 16. Piping system.

Figure 17. Piping system.

Figure 18. Headbox.

Figure 19. Parshall flumes installed in furrows, test site #1.

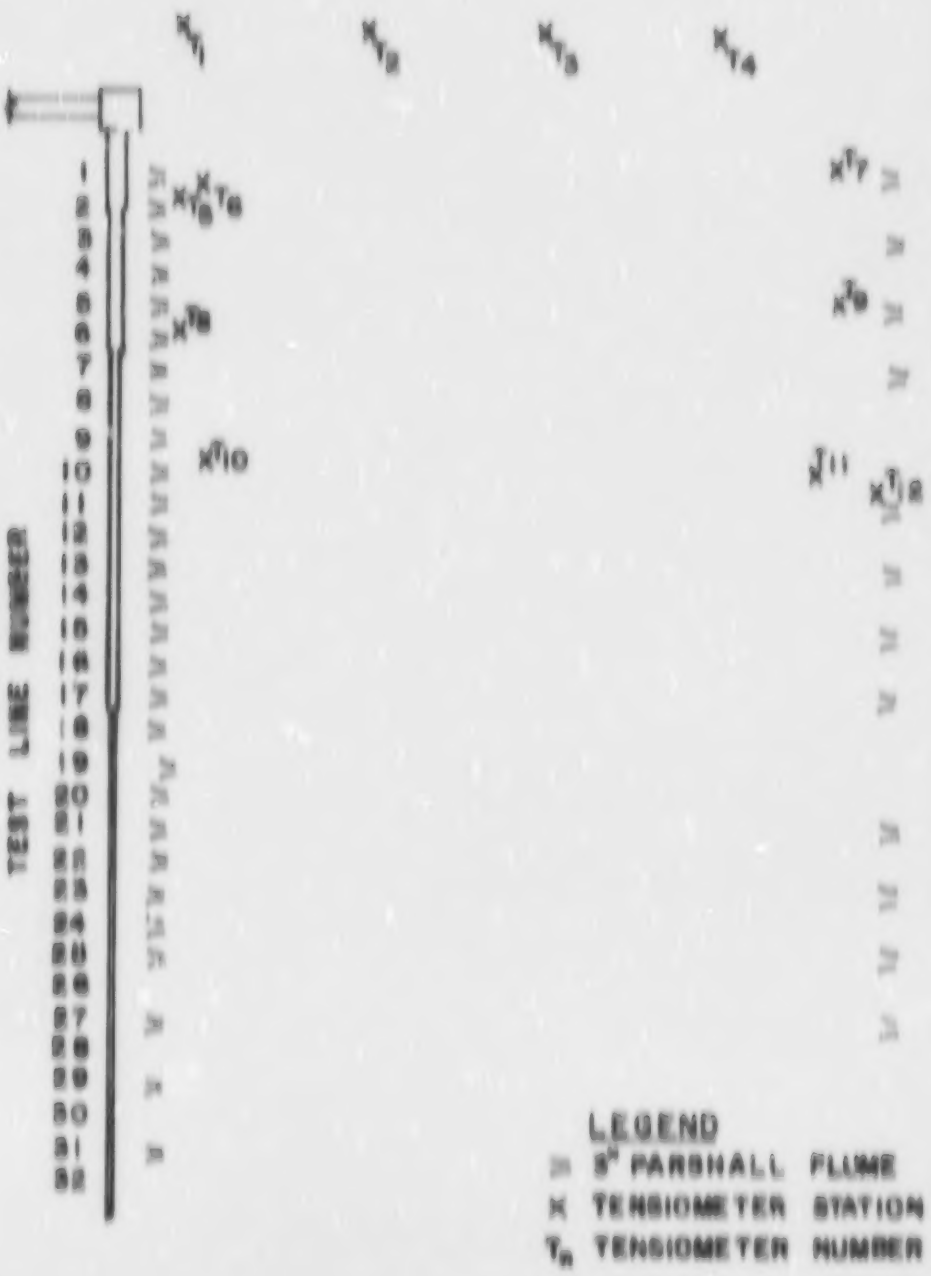


Figure 20. Plan view of test area.

Figure 1. Fernhill measuring frame.

Figure 2. Tensiometers in furrow.

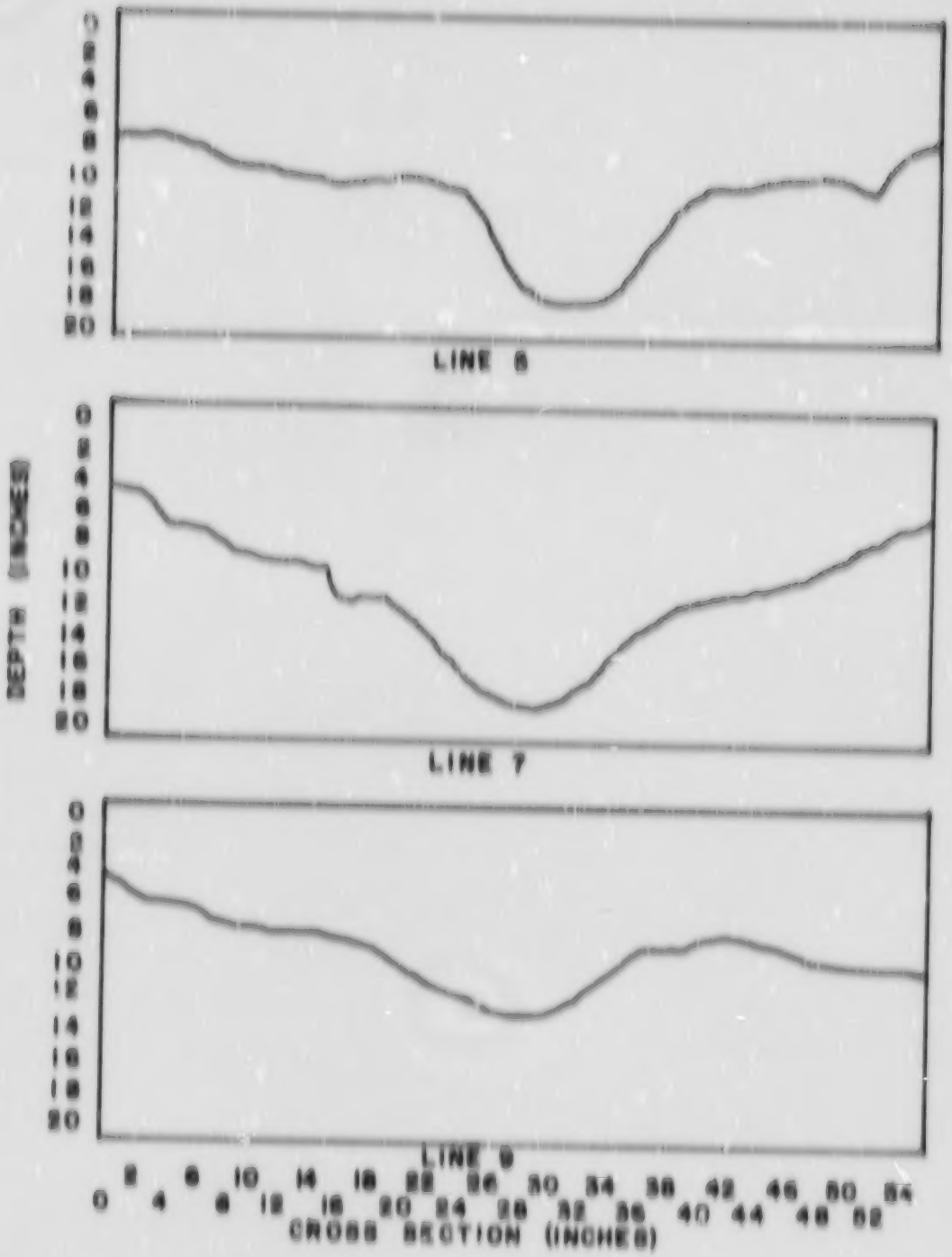


Figure 23. Furrow cross-sections.

TABLE 7. TEST SITE #1

Land containment field S & D furrow grades in % slope

Furrow No.	First 25*	Second 25*	Third 25*	Fourth 25*	Average For 100*
1	1.3	0.0	1.0	1.9	1.1
2	(1.0)	0.4	4.4	1.7	1.9
3	(0.6)	0.8	3.8	1.1	1.3
4	(1.0)	1.3	4.1	0.7	1.3
5	0.6	0.6	3.7	1.3	1.4
6	(0.6)	1.3	3.1	1.8	1.7
7	(0.3)	0.9	2.5	3.9	1.8
8	0.3	0.0	2.9	3.0	1.6
9	0.4	0.0	2.6	3.0	1.5
10	1.5	0.0	2.1	1.8	1.3
11	1.0	1.0	2.3	2.8	1.8
12	0.4	1.2	2.0	0.3	1.0
13	0.8	1.1	1.1	3.5	1.6
14	0.9	1.2	1.0	2.5	1.4
15	0.5	0.8	1.7	3.0	1.5
16	1.0	1.2	2.1	3.1	1.8
17	0.5	1.3	1.6	2.2	1.4
18	0.0	1.1	2.6	2.2	1.5
19	1.2	1.0	2.8	1.3	1.6
20	(0.3)	2.0	2.6	2.8	1.8
21	0.3	2.6	1.5	2.6	1.8
22	1.1	2.8	0.3	2.9	1.8
23	1.4	1.5	2.3	3.3	2.1
24	2.3	1.0	2.8	3.0	2.3
25	2.0	1.0	3.0	3.0	2.3
26	1.8	1.6	2.9	4.0	2.6
27	1.4	1.3	4.0	3.3	2.5
28	0.8	2.1	3.8	2.3	2.0
29	0.9	3.2	3.5	3.4	2.7
30	0.5	2.6	4.0	4.2	2.8
31	1.0	2.8	4.6	4.8	3.3
32	1.1	3.2	4.6	5.7	3.6

*distances given in feet

TABLE 8. TEST SITE #1 DATA

Row No.	Elapsed Time (Min.)	Inflow (gpm)	Outflow (gpm)
1	48	50	45
3	60	45	30
5	20	27	25
7	20	25	16
11	25	16	8
13	30	8	0

Apparent infiltration rates for various test runs at site #1 are given in Appendix B. Figure 24 shows the infiltration rate as it varies with water application. Two things are immediately evident: 1) the infiltration rate has a general downtrend as water is applied and reapplied, and 2) the greatest rates of infiltration decline are those times in which the soil has not "rested" for several days between applications. It should be noted however, that other factors will also influence these tests; among them are rainfall, evaporation, wind velocity, total solids in the water, etc.

The tensiometer readings for this time are shown in Figures 25 and 26, the lower the reading, the more moist the soil. As one would expect, the highest readings are observed for the baseline tensiometers located just outside of the test site, with the 6" one being considerably more responsive than the one buried at 18".

The lowest readings are exhibited by the tensiometers located directly within the furrow, with those located between furrows showing slightly higher readings. As before, the ones buried at a 6" depth are more responsive.

As water application during a test corresponded to rainfall of up to three inches per hour (depending upon row and test), it is not surprising that the tensiometers are more responsive to the test water than rainfall.

An evaporator pan was also in operation during part of the tests. Evaporation readings averaged ≈0.14 in./day.

It was soon evident that there were two major problems associated with disposing of wastewater in growing cane. The first was that normal planting practices called for furrows much too small to handle the sediment load expected. The second, was that as the cane grows it both falls over and releases trash (dead leaves, etc.) which clog the furrows, thus limiting their usefulness.

Other things learned were that furrow slopes had to be minimized, otherwise too fast an advance rate resulted (a 3% slope was found to be too great).

A second test site was then developed adjacent to site #1 (Figure 15). This site (#2) consisted of a preliminary test of trenches for wastewater

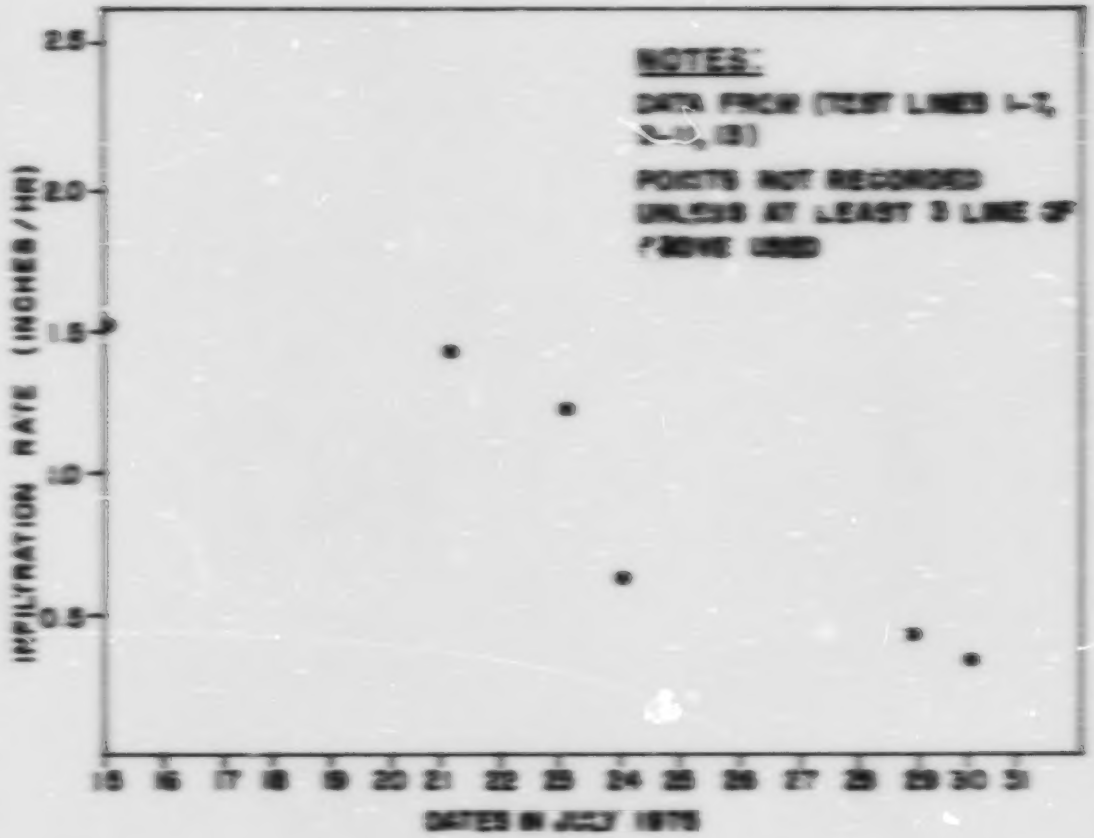


Figure 24. Test lines 1-7, 9-11, 13.

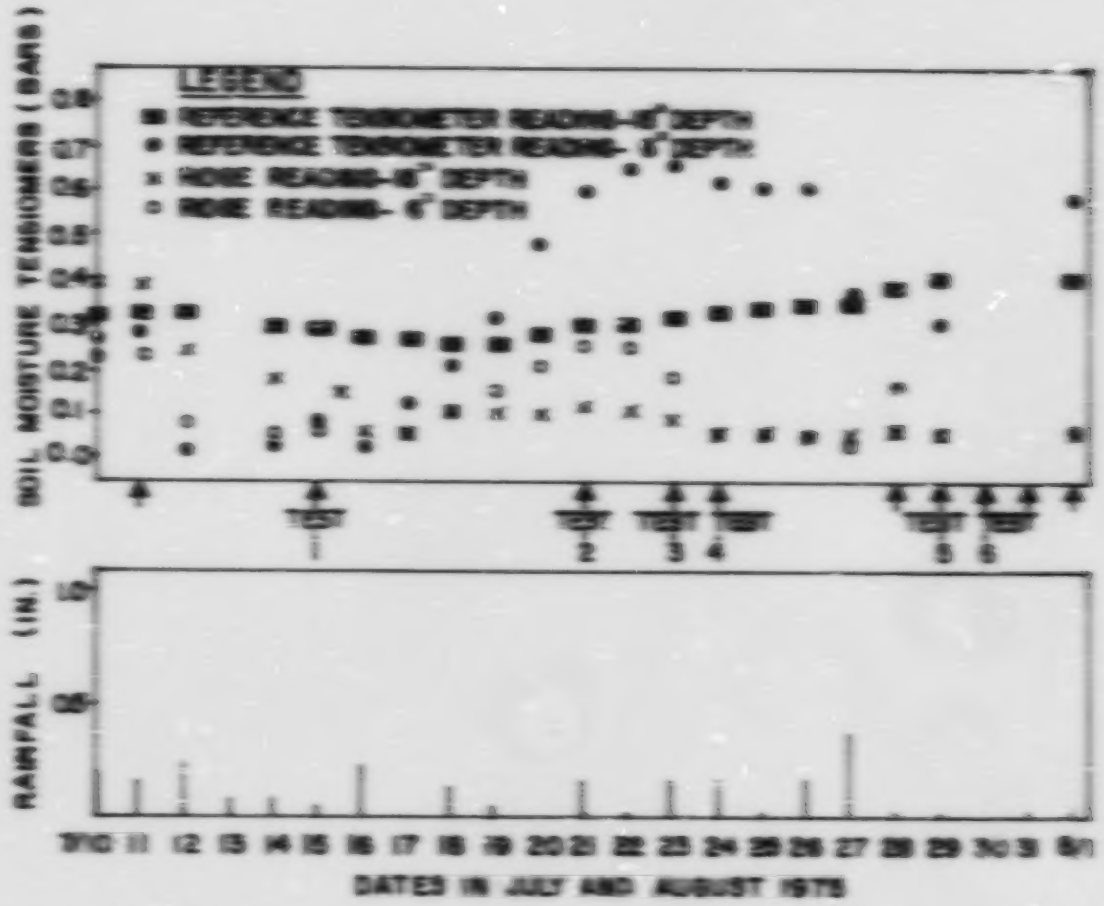


Figure 25. Tensiometer data.

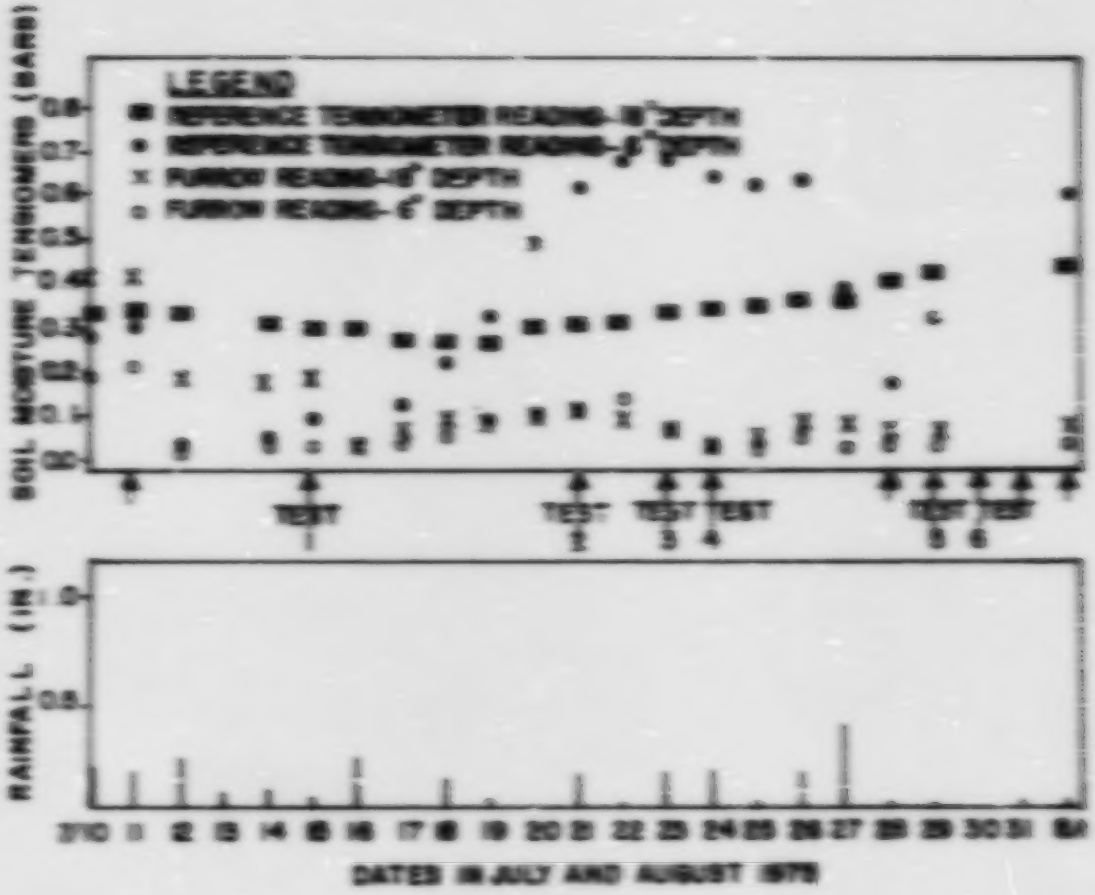


Figure 26. Tensiometer data.

disposal. Two trenches were dug with a backhoe. Their dimensions are given in Table 9.

TABLE 9. TEST SITE #2 TRENCH DATA

	Trench #1	Trench #2
Length (ft.)	479	279
Width (ft.)	2	2
Height (ft.)	2	2

Yardsticks were placed periodically down the lengths of the trenches. Their placement in trench #1 are shown in Table 10.

TABLE 10. YARDSTICK PLACEMENT, TRENCH #1, SITE #2

Stick No.	Location (ft.)	Relative Elevation (in.)*
1	26 from start of trench	0
2	50 from stick #1	- 11
3	60 from stick #2	- 15
4	50 from stick #3	- 8
5	50 from stick #4	- 4
6	50 from stick #5	- 7
7	50 from stick #6	- 5
8	50 from stick #7	- 5
9	50 from stick #8	- 12
	43 from stick #9 to end of trench	

*Depth of trench relative to location at stick #1.

The yardsticks were used to measure silt-up rate, advance rate, and infiltration rate (rate at which water height declined). Trench #1 had an overall slope of ≈ 2.5% from beginning to end.

It was first planned to put only clean water into the trenches such that a baseline infiltration rate could be determined. However, water was being supplied from the Papaikou cane cleaner and its operation was so intermittent that a reliable source of clean water only or dirty water only was not available. Thus we were forced to use whatever quality water was available. Typical data sheets for test site #2 are given in Tables 11 and 12.

Total water intake into the two trenches is given in Table 13.

TABLE II. TEST SITE #1 DATA SHEETS

Time Start	Time End	No Flow (min)	Flow min	Flow Avg. gpm	Flow Total gal	Test Drive No.* 1	2	3	4	5	6	7	8	9	2nd
900	1138	498													
1138	1201		23	82.5	1898	1139	1141	1143	1155						
1201	1230		31	142.5	4415					1243	1252				
1230	1302		32	185	5550										
1302	1327		25	167.5	4188								1310		
1327	1408		41	195	7995									1336	1350
1408	1430		22	207.5	4565										
1430	1451		21	152.5	3202										
	1453							23.50							
1451	1511		20	105	2100										
1511	1643		92	101.5	9338										
	1643							23.87							
1643	1815		92	94	8648										
	1815							24.37							
	2012							20							
	2208							16.87							
1815	2400	345													
		1043	397	134.7	51902										

NOTE:
Untreated dirty water
Rate of depth increase: from 1138 to 1815 (397 min or 6 hr 37 min)
inflow 137 gpm
depth increase @ #3 from 6" to 24-3/8 = 18-3/8"
There is 6593 gal of water in trench at 1815

*A time in the particular column indicates time water arrived at this location.
Other numbers indicate depth in inches.

TABLE 12. TEST SITE 4C DATA SHEETS

Time		No Flow	Flow			Test Shot No.**									
Start	End	(min)	min	Avg. gpm	Total gal	1	2	3	4	5	6	7	8	9	End
0720	921	501					14a	12.8a	6.3a	4a	8.8a	6.8a	6.3a	7.8a	
821	823		2	130.5	261										
823	828		5	111	555				0827						
	825							17.0							
828	834		6	107.5	645					0830					
	829							19.4							
	833							20.4							
834	935		61	112.5	6862							0840	0844	0847	0857
	858							21.5							
935	1026		51	123	6273										
	940					11.0	22.3	25.0	18.4	14.1	19.5	15.8	16.0	24.5	
	955					12.0	23.4	26.3	19.9	15.4	27.8	16.9	16.8	25.5	
	1026					14.5	25.5	28.4	22.0	17.5	22.9	17.4	18.8	27.4	
	1052					17.3	26.4	29.1	22.8	18.3	23.6	19.9	19.5	28.3	
1026	1132		66	120.5	7953	16.0	27.1	30.0	23.5	19.0	24.5	20.5	20.1	29.0	
1132	1205		33	119.5	3944	16.5	27.6	30.5	24.0	19.5	25.0	21.0	20.8	49.5	
1205	1233		28	126	3528	17.0	28.1	30.9	24.5	20.0	25.5	21.5	2...3	29.9	
1233	1302		29	129.5	3756	17.5	28.6	31.4	24.9	20.4	26.0	22.0	21.4	30.4	
1302	1313		11	130	1430										
1313	1327	14													
	1340					16.8	27.8	30.5	24.1	19.8	25.1				
1327	1406		39	130	5070							21.5	21.3	29.9	
1406	1410	4													
	1416					16.8	27.4	30.8	24.4	19.9	25.4	21.5	21.1	29.9	
1410	1435		25	136	3400*	17.9	28.9	31.8	25.5	20.9	26.4	22.5	22.3	31.0	
1435	1501		26	143.5	3731*	19.4	30.0	32.9	26.5	22.0	27.4	23.5	23.4	32.9	
1501	1545		44	145	6380*										

(continued)

TABLE 12. (continued)

Time		No Flow	Flow			Yard Stick No.**									
Start	End	(min)	min	Avg. gpm	Total gal	1	2	3	4	5	6	7	8	9	Bed
1545	1630	45													
1630	1704		34	120	4080	17.1	28.4	31.3	24.9	20.5	26.0	25.0	22.8	30.4	
1704	2000		176	120	21120										
	2019					17.6	27.8	30.5	24.1	19.6	24.9	23.8	23.4	29.8	
2000	2400	240													
		804	636	123.8	78728										

*Clean water

**A time in the yardstick column indicates the water arrived at this location. Other numbers indicate depth in inches.
s = "soapy" silt; b = bottom of trench reading

TABLE 13. WATER INPUT (GALLONS), SITE #2

Date	Trench No. 1	Trench No. 2	Total
8-28-75	36,324	19,250	55,574
8-29	51,902	"	51,902
9-02	35,230	"	35,230
9-03	78,728	"	78,728
9-04	97,929	"	97,929
9-05	9,353	89,673	99,026
9-06	"	32,603	32,603
9-07	"	26,500	26,500
9-08	"	97,675	97,675
9-08	"	62,130	62,130
9-15	27,355	"	27,355
9-16	33,797	"	33,797
	370,618	367,831	638,449

Several dirty water samples were also taken at this time for analysis of total solids. These results are listed in Table 14 (also see Chapter V and Appendix C). The % solids by weight is based upon the weight of solids dried at 100 - 110°C compared to the weight of the original dirty water sample. At the end of the test, it was estimated that trench 1 had 271 ft^3 of silt deposited in it. Silt depth ranged from one foot at the head of the trench to almost none at the tail.

TABLE 14. WATER SAMPLED

Date	Sample #	Empty Dish Wt.(g)	Dish & Wet Sample Wt.(g)	Dish & Dry Sample Wt.(g)	% Soil by Wt.
9-09-75	A0	70.135	162.911	70.3314	0.21
		70.534	158.582	70.7026	0.21
9-11	B1	70.136	146.976	70.3278	0.25
	B2	70.536	164.035	70.7684	0.25
9-15	C1	69.808	159.213	70.0750	0.30
	C2	71.956	155.046	72.2021	0.30
9-16	D1	70.134	149.900	70.2962	0.20
	D2	70.535	148.401	70.6923	0.20

Infiltration (recession) rates were also determined for these trenches, as were advance rates.

Advance rates varied considerably depending on whether it was first application, or whether water had been applied on this section of the trench previously. Some advance rate information is given in Table 15.

TABLE 15. ADVANCE RATES DATA

Date	Trench No.	Advance Distance (ft.)	Time (Min.)	Average Water Input Rate (GPM)
8-27-75	1	26	1	100
		76	4	
		136	27	
8-28	1	136	24	55
		186	42	77
		236	78	84
8-28	2	50	12	51
		100	111	50
		150	171	52

By first filling up the trench and then reading the water depth on the partially immersed yardsticks at specified time intervals, an infiltration, or recession, rate could be calculated. These values were then fit to a curve to the form $W = Ae^{-Bt}$. Where W is the water height in the trench (inches), and t is the time (hours). An r^2 fit of better than 0.9 was found for this model using the following values: A = 32.61, B = 0.02. Experimental and calculated data points are shown in Figure 27. Differentiation of this gives the recession rate (change in water depth with time):

$$\frac{dw}{dt} = -0.65e^{-0.02t}$$

Test site #3 (Figure 15) consisted of furrows made by a ditch plow on an area cleared of cane (Figure 28). The furrows were about two feet deep and three feet wide. It was soon evident that they were not acceptable for the following reasons: 1) the holding capacity of the furrows was considerably less than for the trenches, and 2) the sides of the furrows tended to seal up quite readily, thus decreasing the infiltration rate rapidly.

It was then decided to instigate a larger test of the trench system. Also tested at this new site #4 (Figure 15) was the effect of flocculent addition (see below). Parameters for the trenches at test site #4 are given in Tables 16 and 17.

As some of these trenches were too deep for the placement of yardsticks, 2 x 4 boards were placed across the trenches periodically along their lengths and distances down to the bottom or to the water level, were then measured (Table 16, Figure 29).

Table 17 gives the location of the boards for each trench, and Table 16 gives the exact distance from the board to the bottom of the trench before any application of test water.

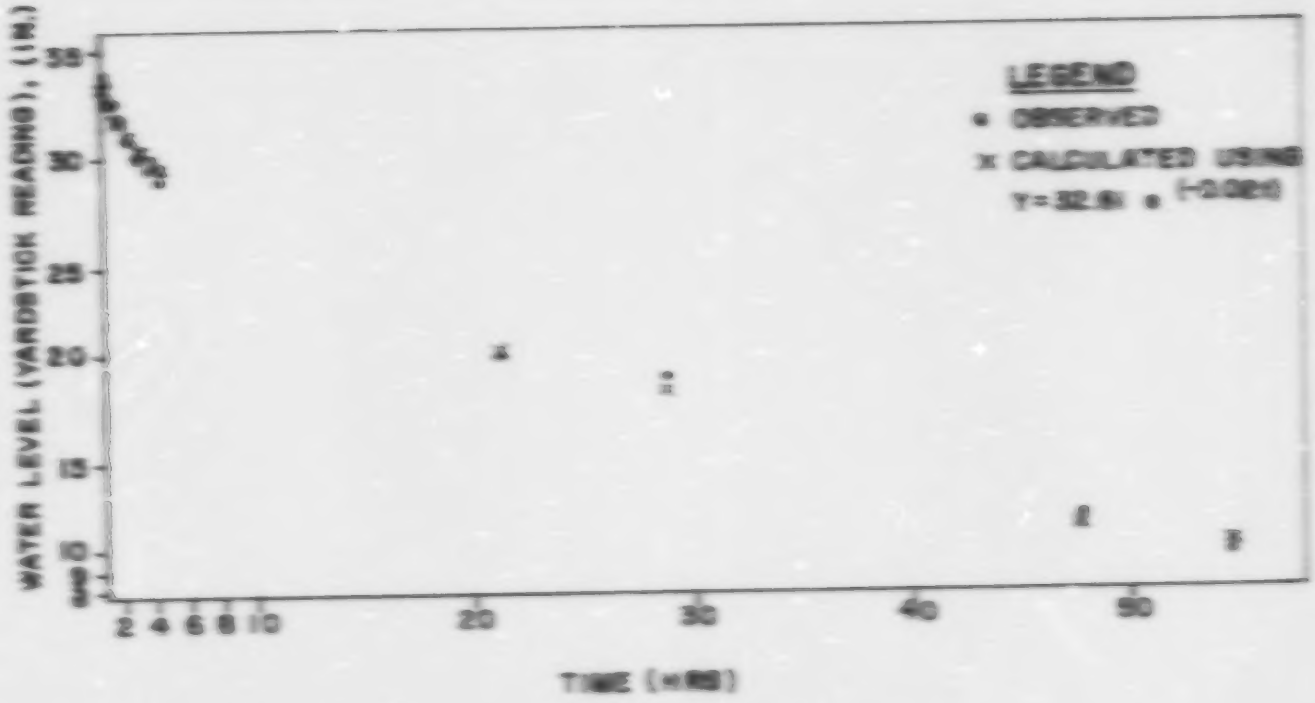


Figure 27. Trench #1.

Figure 25. Test Site #3.

Figure 26. Board placement across trenches.

TABLE 16. ORIGINAL BOTTOM READINGS FROM TOP OF 2 x 4 AT MARK (IN.)[a]

Board No.	Trench A	B	C	D	E	F	G	H[b]	I[c]	J[c]
1	30.0	36.0	35.0	37.5	33.0	33.5	36.0	84.8	48.8	36.0
2	33.5	38.5	36.0	40.0	38.5	36.0	36.3	81.8	55.5	37.5
3	33.0	36.0	34.0	35.0	38.0	37.0	38.0	89.0	63.5	38.5
4	32.0	36.5	33.0	38.5	33.5	38.0	37.0	85.0	60.8	44.3
5	32.0	37.0	33.0	38.0	34.0	41.5	41.0	85.0	63.0	42.8
6	36.0	36.0	35.5	38.0	36.0	40.0	45.5	89.3	57.0	33.5
7	34.0	41.0	36.5	38.0	34.5	38.0	43.5	81.0	58.5	32.8
8	32.5	40.0	35.5	40.0	33.0	39.0	36.0	80.0	68.8	34.5
9	39.0	37.0	38.0	40.0	34.0	38.0	40.5	89.0	67.5	42.5
10	35.0	36.0	33.0	36.5	41.0	43.0	43.0	66.0	66.0	43.5
11	35.5	32.0	38.0	37.0	36.0	36.5	45.0	81.5	67.0	45.5
12						42.0	38.5	72.8	64.0	44.5
13							40.0	57.8	61.9	47.0
14							40.5			45.0
15							36.5		53.0	43.8
16							36.0		39.3	42.8
17										48.0
18										41.0
19										40.5
20										47.8
21										41.3
Average	33.9	36.9	35.2	38.6	35.5	38.9	39.6	80.1	61.9	40.9

[a]read Oct. 15, 1975
[b]read Oct. 21, 1975
[c]read Oct 17, 1975

TABLE 17.[a] BOARD PLACEMENT AND TRENCH PARAMETER

Board No.	Trench A	B	C	D	E	F	G	H	I	J
1	4.7	4.8	5.3	4.0	4.6	4.7	4.3	5.1	5.0	4.9
2	10.0	9.8	11.3	8.8	9.5	9.5	9.3	10.4	11.2	9.4
3	15.42	16.4	17.1	14.8	14.7	15.1	15.5	17.1	19.6	14.3
4	20.3	21.9	23.2	18.9	19.8	20.5	21.3	22.4	25.0	19.7
5	25.5	27.3	28.7	23.6	24.9	25.0	26.4	27.4	31.0	24.8
6	30.6	33.3	34.3	28.8	29.8	31.6	30.8	32.7	36.3	30.1
7	41.0	44.1	46.0	40.3	39.6	42.0	43.1	4.12	44.6	35.6
8	50.9	55.1	56.7	50.9	49.8	49.7	50.3	52.1	58.3	40.9
9	61.8	66.1	68.3	63.2	60.3	60.2	59.9	74.2	76.8	51.4
10	82.3	87.7	87.4	86.6	80.7	80.2	75.6	96.7	96.6	61.9
11	102.8	106.6	109.9	109.0	101.6	100.8	97.0	118.4	120.8	73.2
12						120.1	116.8	146.8	142.3	91.1

(continued)

TABLE 17. (continued)

Board No.	Trench A	B	C	D	E	F	G	H	I	J
13							133.8	175.3	177.3	
14							147.8		211.2	110.1
15							182.0		256.2	130.8
16							205.5		325.2	150.7
17									385.6	171.2
18										191.9
19										239.9
20										282.4
21										327.4
22										375.4
Width	2	2	2	2	2	2	2	2	1	1
Depth	3	3	3	3	3	3	3	7	5.5	3
Length	116	116	116	116	116	144	219	188	420	394

*Distance from beginning of trench (feet)

The bottom of trench F was lined with plastic, thus preventing the exiting of water through the bottom of the trench. A water input record of several representative trenches is given in Table 18.

Figure 30 shows the decline in infiltration rate as water is added. Note that trench F has its bottom sealed with plastic and that infiltration is thus only allowed out through the sides of the trench. It appears that several applications of dirty water can seal the bottom of a trench almost as effectively as lining it with impervious plastic.

The change in bottom profile for several trenches as they silt up is shown in Figure 31. A summary of the amount of clean and dirty water placed into the trenches is given in Table 19, along with the amount of silt deposited and the approximate percent, by volume, of silt in the dirty water.

If it is assumed that a minimum depth of one foot is needed for the efficient settling out of sediment, the remaining volume of the trench can then be defined as the maximum volume available for silt (MVA). The percent of the MVA which is filled by sediment can then be calculated. This figure is also given in Table 19. This is only an approximate percentage however, because the silt is not deposited evenly, but tends to first come out at the head of the trenches (Figure 32). Thus, this percentage is a minimum and a more practical value may be almost twice this.

Flocculants were also tested in test site #4. Recession rates for several tests are given in Table 20. Figure 33 shows a plot of infiltration rate vs. total amount of dirty water added during these polymer tests. Values approaching that of trench F (bottom sealed with plastic) are observed.

| | | |

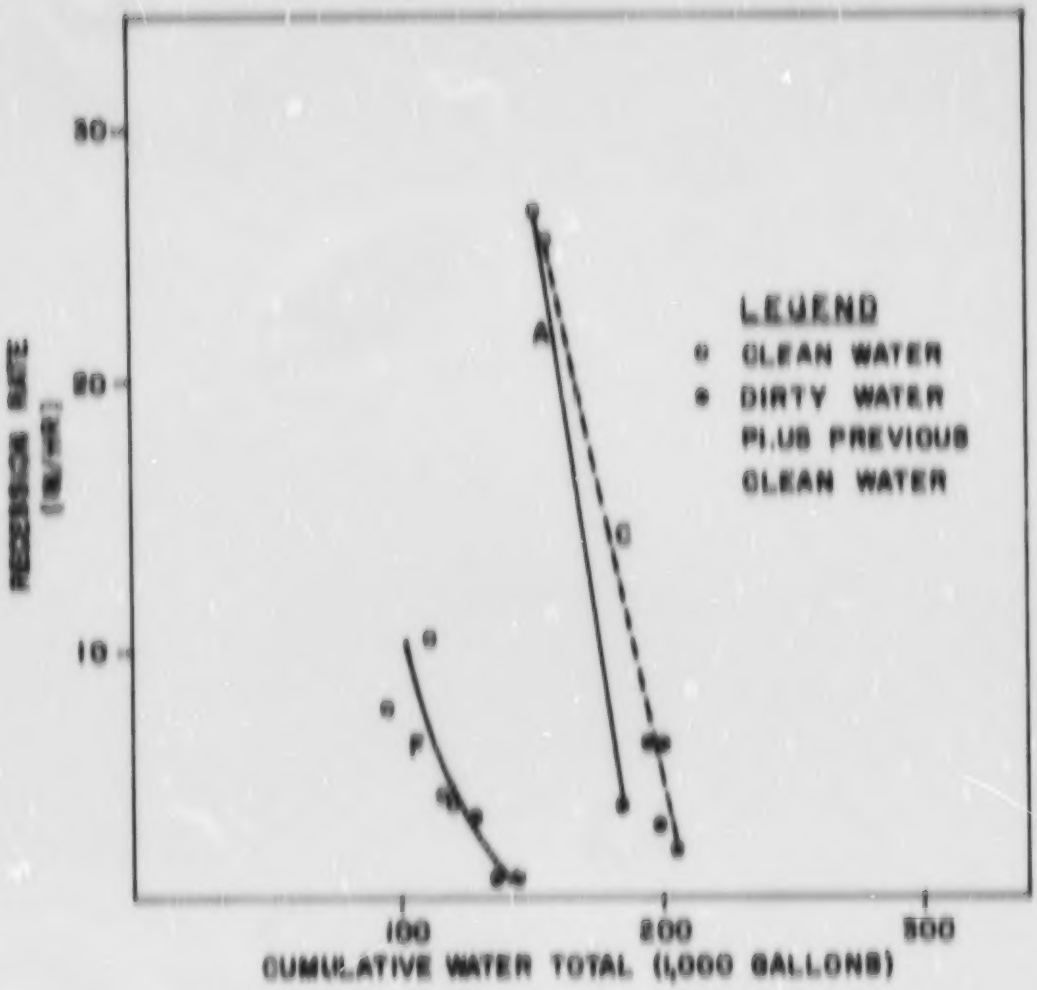


Figure 30. Decline in infiltration rate for several representative trenches.

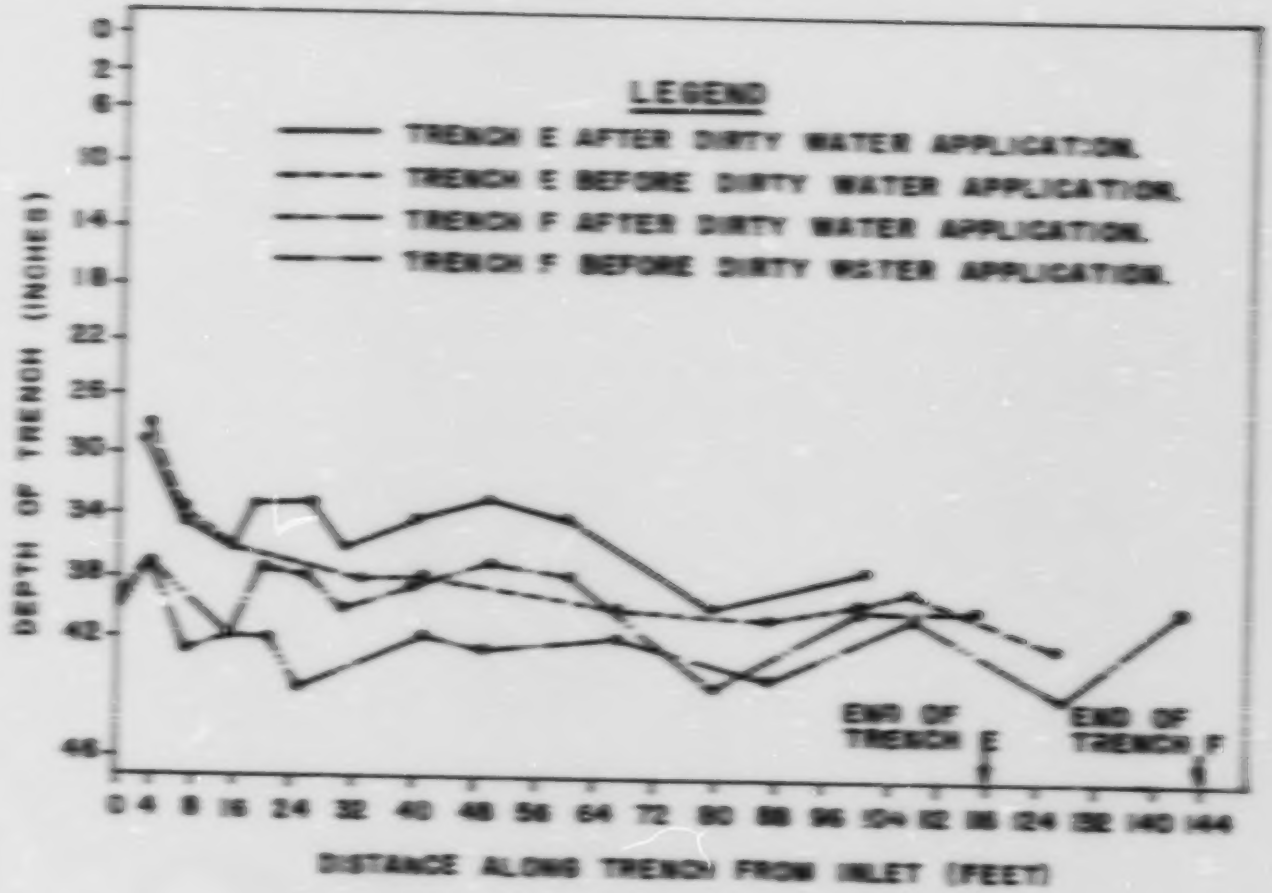


Figure 11. Sediment build up in trenches.

TABLE 19.* WATER INPUT INTO TRENCHES

Trench	Clean Water Gal x 10^3	Dirty Water** Gal x 10^3	Dirty** Water Feet^3	% of MVA Filled by Sediment	Total Silt+ Deposited Feet^3	% Silt+ by Volume in Dirty Water
A	181.94	9.65	1,286	19.6	91	7.1
B	148.64	28.44	3,791	72.6	337	8.9
C	189.90	29.96	3,994	68.1	288	7.2
D	183.79	29.09	3,878	57.8	268	6.9
E	203.41	12.47	1,663	45.9	213	12.8
F	122.07	22.22	2,962	43.8	252	8.5
G	162.55	26.78	3,837	34.9	306	8.0
H	114.20	21.72	2,895		***	***
I	0.0	42.02	5,602	32.0	605	10.8
J	57.70	25.96	3,463	41.0	323	9.3
	1,364.20	182.28	24,300		2,683	avg. 8.8

* As of November 25, 1975
** Screened through 1/16" screen
*** Final measurement on trench not completed due to weather conditions and slowness in drying
\+ Excluding trench H

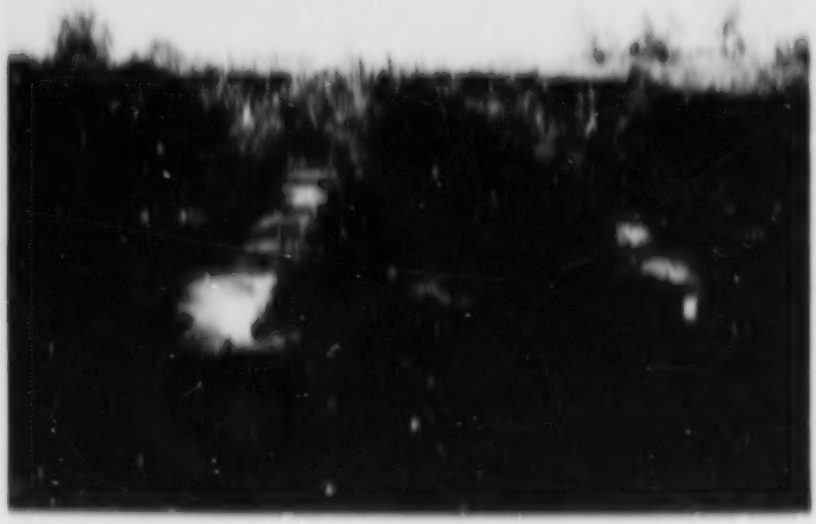


Figure 10. Note how silt has deposited predominantly at beginning of trench.

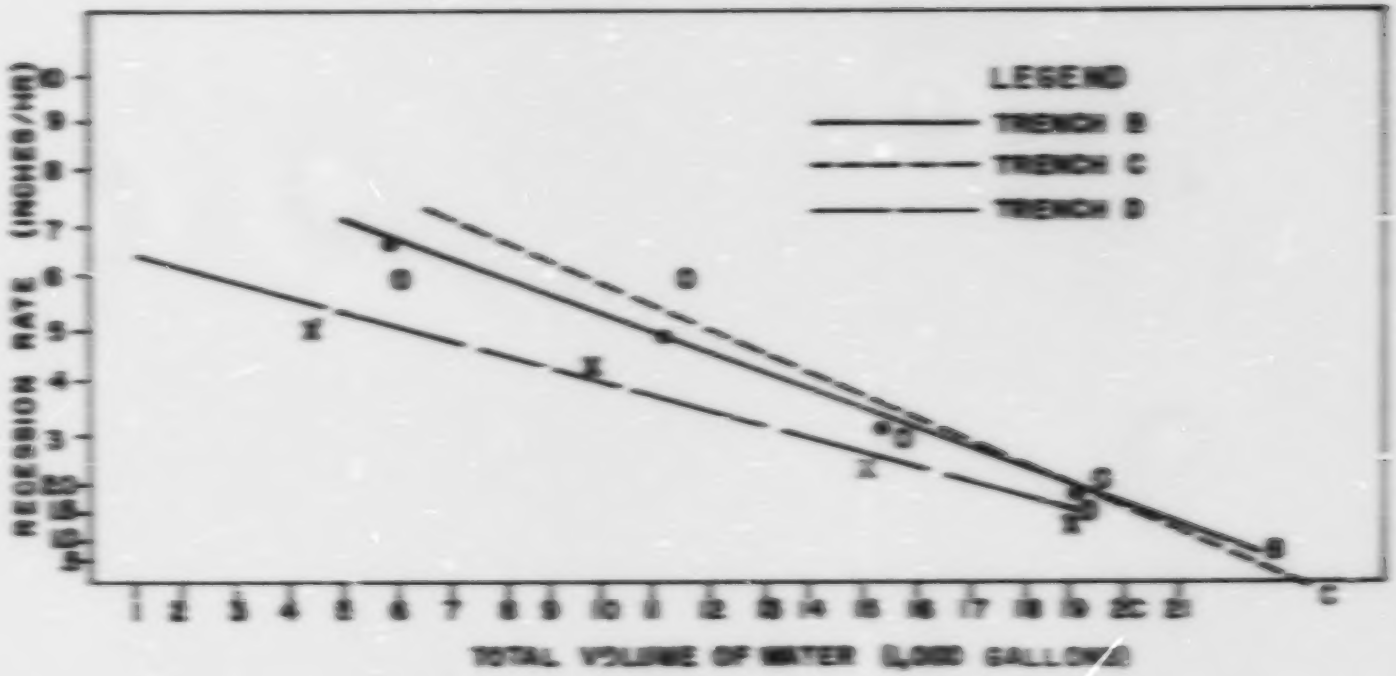


Figure 33. Decline in infiltration rate for several representative (i.e. B, C, and D) trenches (polymer test).

TABLE 20. POLYMER TEST RECESSION RATES

Date	Trench*	Recession Rate (inches/Hour)	Water Volume (Gal x 10^3)
11-04-75	B	6.6	5.84
	C	6.0	6.24
	D	4.8	4.97
11-05-75	B	4.8	5.20
	C	6.0	5.24
	D	4.2	3.49
11-07-75	B	3.0	4.30
	C	3.0	4.30
	D	2.4	5.07
11-11-75	B	1.8	3.7
	C	1.8	3.7
	D	1.2	3.7

* Trench B - Dow Purifloc A-23, 1 ppm
Trench C - Nalco 677, 1 ppm
Trench D - Control, no polymer

The near linearity of this plot should also be noted. Also see Figure 30 which shows similar declines.

Observations made during these tests indicated that although the removal rate for the first hundred feet or so of a trench was greater when using polymers, the absolute amount of silt settled out, or percent of total silt present which was settled, was not substantially different from the no-polymer control. The only advantage of this action would possibly be that shorter trenches could be used. A disadvantage would be that material would pile up quicker at the head of a trench, slow down a more even distribution, and thus shorten the life of a trench because the minimum depth needed for settlement would not be present as long. Thus, at this stage, polymer usage did not appear to represent a viable addition to the land containment system.

A decanting device (designed by R. Ferguson) was also tried out in test site #4. The rationale for this is as follows: As seen above, as the trenches receive more and more silt, their infiltration rate decreased. The trenches are soon at a point where the suspended solids will still settle out, but the water will not infiltrate at a satisfactory and practical rate. It was then thought that perhaps a two-trench system could be used. In this system, dirty water would only be allowed in one type of trench (settling trenches - SWT). The second type of trench (clean water trenches - CWT) would then be used for water from which the suspended solids had already been essentially removed (>90% removal). The decanting device, as shown in Figure 34 and 35, was used for the water transfer. It has the advantages of taking the water from just below the surface - thus avoiding any floating material; and, because it floats, it is able to take the water level down almost completely to the bottom of the trench. The advantages over a simple overflow device are evident. Figures 36 and 37 show the decanting device as it feeds a CWT.

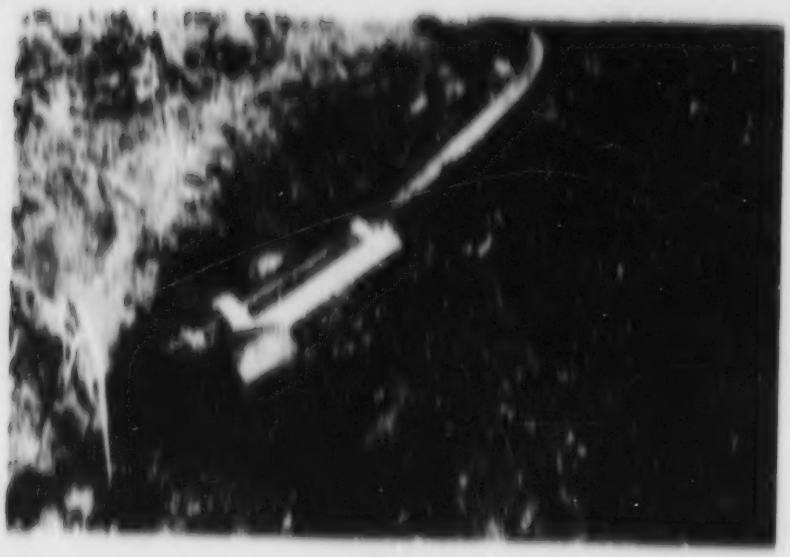
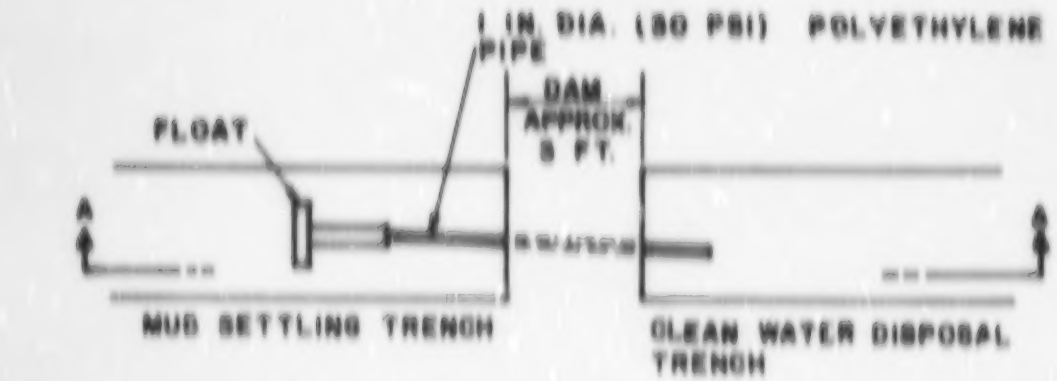


Figure 34. Decanting device.

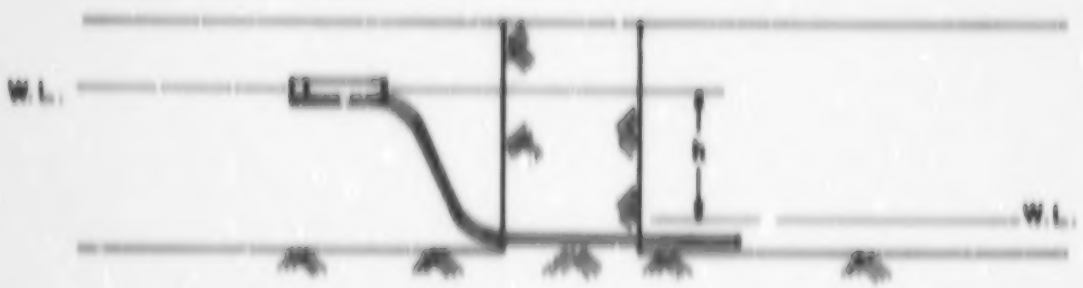
Test site #5A,B, (Figures 15, 38) was designed with the two-trench system in mind. The original plan for test site #5A,B, was to alternate using sites A and B, approximately every three to five days. The purpose of this was to eliminate having any water standing for more than three days, because after three days odors and mosquitoes have a potential to develop. Also, the longer the land can "rest" between applications the better the infiltration rate, as previously noted. Unfortunately, only test site #5A was completed when we were ready to move from site #4 to #5A, B. The reason digging went slowly was because it was all done with a backhoe (Figure 39), which is a slow digging machine, especially in the rain and wet slopes it was necessary to work on (a trenching machine (Figure 40 purchased in December, 1975), was not actually field operational until April, 1976. In order to use test site A to best advantage the following were done: 1) 0.4mm screens (Figure 41) were set up in the field, just prior to the water input to site A, such that water screened to the degree planned in the final dry-cleaner modification would be available for the tests, and 2) the field was divided into two dirty water sections such that a "rest" time could be incorporated. Unfortunately, the slope and design was such that the fresh water trenches could not be divided up - so that they were used continually. This led to some problems as discussed below.

Test site #5A ran for approximately two weeks before the Papaikou mill was shut down for scheduled annual maintenance. It was the largest test site to date, comprising about 3600 ft. of trench (down from the original plan of 4200 ft. because of the room needed for piling the dirt excavated from the trenches).

A flow meter was set up between the 0.4mm screens and site #5A, but unfortunately it sometimes clogged and therefore, all water was not recorded.



PLAN VIEW



SECTION A-A

Figure 35. Decanting device.

Figure 36. Bed of eighon base.

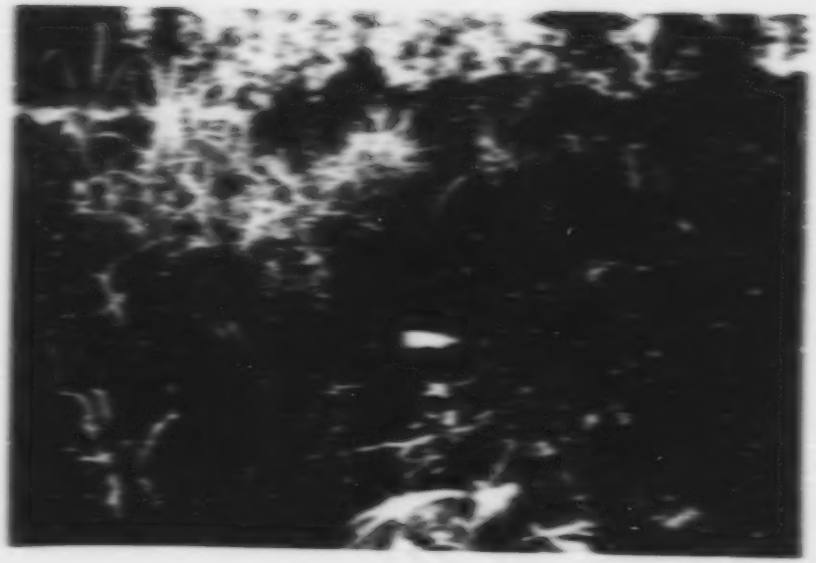


Figure 37. Bed of eighon base Exchanging into a CM.

Figure 38. View of test site #5A.

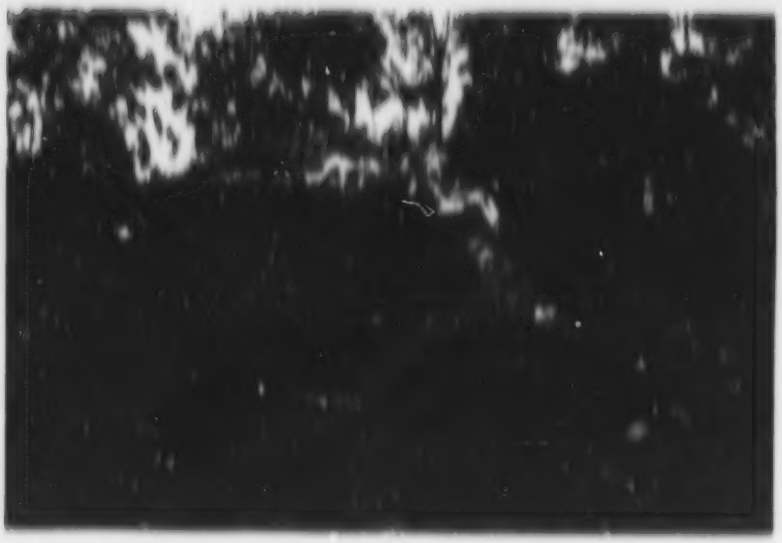


Figure 39. Backhoe at test site #5A.

Figure 50. Trenching machine

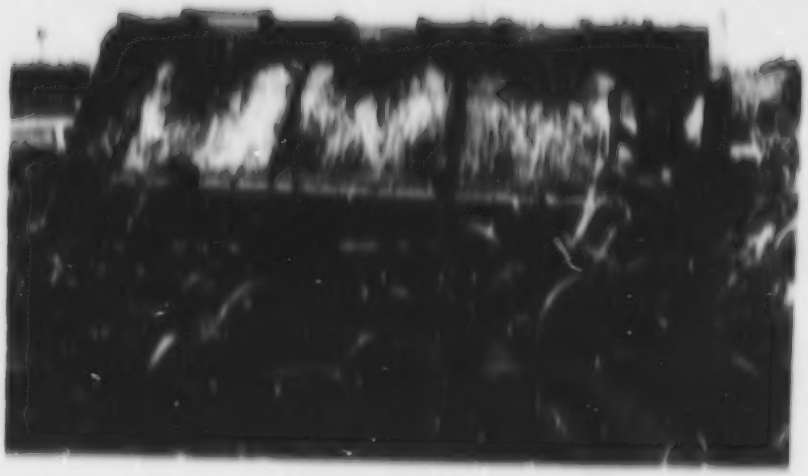


Figure 51. 0.5mm screens set up in field.

It is estimated that about 3.36 million gallons of dirty water was placed on site #5A. The output from the screens was 350 gpm, this represented a running time of 160 hours. This would represent about 80 hours per section for the DT, but a full 160 hours on the CWT.

The CWT were not able to dispose of the decanted water satisfactorily. The reasons are two-fold. First, in planning the length of CWT, those not on zero grade were considered part of the allocated area. In practice, those lengths not on zero grade served merely to convey the water to the zero grade areas near the bottom of the test site and did not disperse of much water themselves. Thus, the amount of trench which was actually disposing of fresh water was less than planned. In an effort to remedy this, dams were placed periodically along the non-zero grade stretches in an effort to hold the water and increase the contact area and time. These helped for only a limited time, as the dams tended to wash away in the areas most needed (those with slopes furthest from zero grade).

The second problem with the CWT was that they were used continuously and not allowed to rest. Thus their infiltration rate was not maximized. Rainfall at the test site during this period (January 1 to February 15, 1976) totaled over 2) inches--about 1/2 inch per day (see Appendices D and E).

In addition, at the beginning of the test, some dirty water was inadvertently allowed into the CWTs. This decreased the infiltration rate considerably under what it should have been along several lengths of clean water trenches.

The DTs were also discovered to be off-grade. This represented a serious problem as it resulted in part of the trench not receiving any water while another part of the same trench could be overflowing. An attempt was also made to alleviate this problem through use of dams. Once again they were marginally successful, being hardest to establish where most needed (where the slope was most different from zero grade).

The DTs at test site #5A were filled from the center, rather than the end of the trench. If the trench is slightly off-grade at the point of water entry, silt could be built up in such a manner that the water is only directed in one direction along the trench, rather than down both sides of it. This prevented full utilization of the full length of a trench. This problem was encountered at site #5A.

The decanting device worked quite well during all tests at test site #5A. A new, easier-to-make model of this device is currently undergoing tests (Figure 42).

Although test site #5A was not a complete success in being able to handle all of the water input into it, much valuable information was learned from it, of which most important was the necessity of zero grade. In order to make maximum utilization of a trench, it must be on or near zero grade. This increases both the area and the time the water and the trench surfaces are in contact.

Figure 42. New siphon design.

In planning the area allocated to CWT, non-zero grade trenches which primarily convey water and that do not actually hold it should not be considered part of the area allocated to CWTs.

In addition, provisions must be made for the "resting" of trenches especially during times of the rainy season (see Appendices D and E).

Another thing learned was that extreme care must be taken to prevent the introduction of dirty water into the CWT system at any time. As seen previously, even a small amount of dirty water can seriously affect the infiltration rate in a negative manner.

The next stage of development is installation of test site #6. This is located above the flume (see Figure 19). It will allow three alternate modes of operation. First, site #6 can be operated as was site #5 with two sets of of trenches (DT and CWT) for the practice of zero discharge. A second mode would be decanting from the DT directly into the flume (Figure 43) for discharge through an authorized discharge point (providing the water meets permit limitations). A third mode would be decanting into the flume and then reuse or recycling of the flume water back into the cane cleaner (or factory). Modes two and three are currently the most favored to be tried at this time. The trenching machine began work in April, 1975, and site #6 became operational during the month of May, 1976.

Water going to site #6 is first passed through 0.4mm screens installed at the cane cleaner in May, 1976.

It is planned, in the near future, to try out a sprinkler for dirty water disposal (Figure 44). The water will be sprinkled on growing cane,

Figure 43. Flume between test sites #5 and #6.

Figure 44. Sprinkler to be set up at test site #7.

and/or trash which has been spread out over a field. Water to the sprinkler will also be prescreened through a 0.6mm screen. This test (site #7) should be in operation about July of 1976.

Examination of early test sites reveals that very little is growing on the silt that had been deposited (Figure 45). Further examination of the silt reveals that it is still soft at places and appeared anaerobic. It is black in color and has the characteristic hydrogen sulfide odor when one digs just an inch or two under the surface.

Figure 45. Note lack of growth on silt deposited in ditch.

When some of the black material was dug up and exposed to the air, it rapidly turned the normal brown color of adjacent soil.

Samples of this black material were checked for pH and Eh (oxidation-reduction potential) both in Hilo at the Crop Log Laboratory and in Honolulu by Professor T. Kaneshiro of the University of Hawaii. A potential difference of about 500mv was recorded between the black deposit and adjacent soil on samples analyzed in Hilo with the time lag of about one hour from sample collection to analysis. Samples analyzed at the University of Hawaii which had a collection to analysis time of 24-48 hours, showed a difference of about 120mv. Thus showing that the deposited silt was in a much reduced state compared to the "normal" soil. pH differences between the two soils were negligible, all being in the 5.4-6.0 range.

Dissolved oxygen (DO) was measured for the water at the dry cleaner going to the field. After being used in only one washing, the DO of the washwater was 7.5 ppm. It was then measured again just before being pumped to the field and a value of 5.5 ppm was observed. Later, water was measured

in the trenches which had been sitting in the trench for 18 hours. Water at the input end of the trench showed 1.3 ppm DO, while half way down the trench 0.7 ppm was observed. One week later, the deposit in the bottom of the trench was examined and found to be the same black deposit as found in previous trenches.

NH_4-Nitrogen: NO_3-Nitrogen ratios were also looked at between the surface brown soil and the subsurface black deposits. Surface soils showed ratios of approximately 1:2, while the subsurface black material had ratios of from 2:1 to over 70:1.

SECTION 6

WATER ANALYSIS

As soon as the necessary equipment and sampling containers arrived, sampling of dry cleaner water sent to the test sites was initiated. Appendix C shows a survey of these water analyses.

In addition to the analysis for total solids, several samples were also ashed at 500°C. It was assumed that the weight loss in ashing (weight difference at 500°C from 100°C) was totally due to loss of organic matter. This should be taken as an upper limit, since some of the weight loss could have been due to loss of water of crystallization or chemical decomposition of inorganic matter.

In addition, several samples were analyzed for suspended, dissolved and settleable solids. These results are shown in Table 21.

Sampling problems were a prime concern in these analyses. This is because of the heterogeneous nature of the sample and its wide variability over time. The reason for this is easy to see: As the cane and water meet in the dry cleaner, there will be times when the water is washing large pieces of dirt from several cane stalks simultaneously and there will also be the opposite extreme of having the cleaner stopped for several minutes (for minor repair or rock removal) with no cane but water running. These two extremes occur within minutes of each other, and thus result in very dirty water entering the field at one moment, and fairly clean water entering a few minutes later. Therefore, the numbers given in the tables are only representative of values encountered.

The two most important observations made from Table 21 and Appendix C are the reduction of suspended solids as water passed down a trench, and the partition of total solids between suspended and dissolved.

For example: At test site #1, the test site which contained the smallest ditches and the fastest advance rate, a reduction of 77% in total solids is observed by having the water travel 150 ft. down these small ditches. Figure 46 shows some results of total solids reduction vs. distance at test site #4. It should be noted that 100% removal of total solids is not possible because of the dissolved solids present (see below).

Figure 46 also shows the typical initial rapid settling of the suspended solids. However, a truer evaluation for removal efficiency is based, not upon total solids, but upon suspended solids. For example, a removal

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| | | |

TOTAL SOLIDS REMOVAL FROM INPUT INTO TRENCH (%)

efficiency of 88% is seen in Table 21 for December 2, 1975 based upon total solids. However, if only suspended solids are considered, a removal efficiency of 99% is achieved.

The percent organic matter rises considerably as the settleable solids are removed. This implies that the dissolved solids are predominately organic. Another interesting note is that the BOD_5 remains essentially constant regardless of suspended solids removal. The conclusion that can be drawn from this is that the dissolved solids are predominately organic and that they account for most of the BOD_5. A semi-quantitative test for sugar in the water showed a concentration of about 0.1-0.05%.

Because of the concern for soil clogging, mentioned earlier, the sodium adsorption ratio (SAR), developed by the U.S. Department of Agriculture Salinity Laboratory, was also determined. An SAR of less than one was found. As this is considerably below the value of nine suggested to be detrimental to soil permeability, it was assumed that a high sodium ion concentration was not appreciably responsible for the decline in soil infiltration rates.

SECTION 7

JUICE WASHING

In juice washing, the cane was to have been washed with the cane juice previously extracted from the cane, and before the juice was processed into sugar. In this way, the sugar cane juice normally washed out of the cane during wet washing would not be lost. However, this concept was dependent upon the success of the CMM system because the juice washing is limited in the amount of soil it is capable of removing. Thus, the majority of the trash and soil had to be previously removed before the cane got to the juice washing stage of the cleaner (the only wet washing then planned).

However, because the CMM system failed to adequately remove soil and trash as hoped, it became necessary to use several wet washings to remove the soil adequately. The juice washing concept was therefore abandoned until future trash and soil removing capabilities become available.

SECTION 8

CANE CLEANER

As previously stated, when the sugar mills operating in Hawaii switched from hand harvesting to mechanical harvesting, enormous quantities of cane trash, soil and rocks were transported to the mill along with the cane which was to be processed. The mills located along the East coast of the island of Hawaii were close to the ocean and had available an abundant supply of fresh surface water. They all, therefore, constructed cane cleaning plants along similar lines. The cleaning plant built in 1948 at Papaikou factory was fairly typical. Soil was removed by drenching the dirty cane with water. Leafy trash was stripped off by a series of rotating rolls. Rocks were removed in a flotation section. The cane, nearly clean, was then flumed by clean water to the factory, a distance of about 600 feet. At the factory, the water was removed in a conveyor with a perforated bottom. At this point the cane, by now quite clean, was ready for milling.

This system used water at a rate of about 12 to 20 million gallons per day (mgd), depending upon availability of water and all of the effluent was flumed to the ocean. Because fresh water was so readily available, no attempt was made to reuse any part of the waste effluent. This cane cleaning plant was in use successfully from 1948 until 1 November 1975.

As more and more national emphasis was placed on pollution abatement it became evident that at some time in the future the amount of soil discharged into the ocean would have to be drastically reduced, or possibly eliminated completely. A new cleaning plant was designed, and in 1975 was placed in operation. It was located adjacent to the old cleaning plant and connected to the factory in such a way that either plant, but not both at the same time, could supply clean cane to the mill.

The design of the new cleaning plant was based on the concept of dry-cleaning. This concept had been tested earlier in a pilot scale dry-cleaner built at another factory and had worked with some degree of success. The pilot scale dry-cleaner was located in a dry area, however, and the success it had in cleaning cane was due in large part to the initial cleanness of the harvested cane being delivered to it. This fact was appreciated by the designers of the dry-cleaner at Papaikou factory, which is in a very wet area (160 in/yr average rainfall). The harvested cane was very dirty and it was intended to compensate for this by developing a harvester-cleaner which would be capable of delivering reasonably clean cane to the new dry-cleaner. The harvester-cleaners were part of the CHH system previously described.

Figure 47 is a scale drawing of the dry-cleaner. In this drawing cane moves from right to left. As it is flung over the carding drum it is spread out on elevating conveyor, C2. As it drops from C2 onto the first soil rolls an air blast from the first blower blows trash and dirt through the gap above the soil rolls onto T1. The cane falls over the rotating soil rolls that knock out more dirt and trash into conveyor T2. Conveyor T1 also conveys its load of dirt and trash into T2. This cleaning cycle is repeated on the second blower except that fresh water sprays were installed over the second soil rolls and the residual dirt was washed down through the second soil rolls and flumed to the ocean.

During the period to December, 1975, cane harvested by the harvester-cleaner was processed by the new dry-cleaner and conventionally harvested cane was processed by the old cane cleaner. During the latter part of this period it became evident that more washing with water would be required in the new cleaner since very often the factory would not be able to operate with the new cleaner on the line because of dirty cane. Up to this time the dry-cleaner was still operating as a dry-cleaner because no water was applied to the cane ahead of the blowers. In April, 1975 the 3-inch fresh water line that had supplied the spray above the second soil rolls was disconnected and extended to a point just above and behind the carding drum where it was connected to a 3-inch spray header. A pump and a 10-inch line were installed to bring process condenser water to the cleaning plant. Four 4-inch spray headers were installed above the second soil rolls and connected to the 10-inch line. A pump was installed under the second soil rolls. Two 4-inch spray headers were installed at the top of conveyor C3 and connected by a 6-inch line to this pump. The "dry-cleaner" ceased to be a dry-cleaner. In fact, about 3000 gpm of clean water was being supplied to it. It was noted that even with wet cane, the blowers were still removing a lot of trash. The dirty water in conveyor C3 was drained out through slots in the conveyor floor and flumed to the ocean.

In May, 1975 it was decided that the combination of harvester-cleaner and dry-cleaner would not produce cane clean enough for milling. Since water would be required to clean the cane, the dirty water would have to be disposed of without polluting the ocean. A land disposal system for cane cleaner wash water was selected. Land disposal could only be feasible if most of the large dirt particles could be removed before pumping the dirty water to the field. It was found by preliminary experimental work at the cane cleaner that it was possible to remove naturally conglomerated clumps of dirt of varying size by fine screening prior to pumping. Pumping has a high shear action which tends to disperse the soil to its finest particle size. The simple concept of screening before pumping appeared to provide a potential for removal of up to 60% of the incoming soil.

The cost of land disposal is roughly in direct proportion to the rate at which water must be disposed of, therefore water use in the cleaning plant was curtailed as much as possible. This was done by:

1. recirculation of wash water
2. countercurrent washing
3. high velocity sprays
4. complete cover of cake blanket by sprays

Starting in June, 1976, screens, receiving tanks, and pumps were installed in several locations in the new cleaning plant. In all installations the screens used were Wedge Wire Corp., 48-inch x 48-inch, profile 90-A, 3/8" diameter cross rods, Type 304 S.S. The installation began at the clean end of the plant, left hand side of Fig. 48 (cake moves from right to left). Three screens were installed to handle dirty water from the tank under conveyor C4. It was necessary, at this point, to experiment with curved and flat screen shapes, screen angle and approach configuration. Five modifications were tried before a satisfactory physical arrangement was achieved. The configuration finally used provided a flat upward sloping floor (one inch/foot), a curved weir with a radius of 29 inches joined on a tangent to the screen which was flat and installed on a 45 degree angle with the slots running horizontally.

The plant was designed to handle 1000 gpm. All spray headers as they were installed, or replaced, were 6 inch diameter pipe. Spray nozzles were designed so that one 1-1/4-inch nozzle would impinge on a curved abrasion-resistant plate (9-inch radius, 21 inches long) and produce a flat sheet of water 5 feet wide. Thus four nozzles spaced across a 12-foot wide conveyor overlap and produce a continuous sheet of water. Pump speeds were set to produce 20 psi pressure at the nozzles.

Recirculation was provided in 1975 by the pump installed under conveyor C4. Unfortunately this was the only place where recirculation could be accomplished without making major, basic changes in the cleaning plant structure, as this was initially the only place where recirculation was used. When screens were installed, they were initially 1/64-inch slot openings but as experience was gained through operation, it was apparent that screens with this size opening could not handle the required volume of muddy water. Thus a compromise had to be reached here, and throughout the plant, between hydraulic capacity (large screen openings) and cleaning efficiency (small screen openings). The screens were all replaced with new screens having openings as shown in Fig. 48.

Some screen locations are not shown in Fig. 48. There are six horizontal screens with 1/16-inch opening installed in the top deck of conveyor T2. Twelve linear feet of 9/16-inch perforated plate is installed in the bottom deck. Five inclined screens are shown above conveyor H1 (Fig. 48); actually there are nine such screens. Five 1/32-inch horizontal screens are installed in the top deck of conveyor H1 and one 1/16-inch screen is installed in the left hand end of this conveyor. One 1/16-inch screen is installed in the top deck of conveyor T3.

Just above H3 (Fig. 48) there is shown a single cyclone. This is a schematic representation of the actual installation of five Krebs D6B-12 cyclones (6-inch diameter, 12 degree apex angle) and one cyclone designed

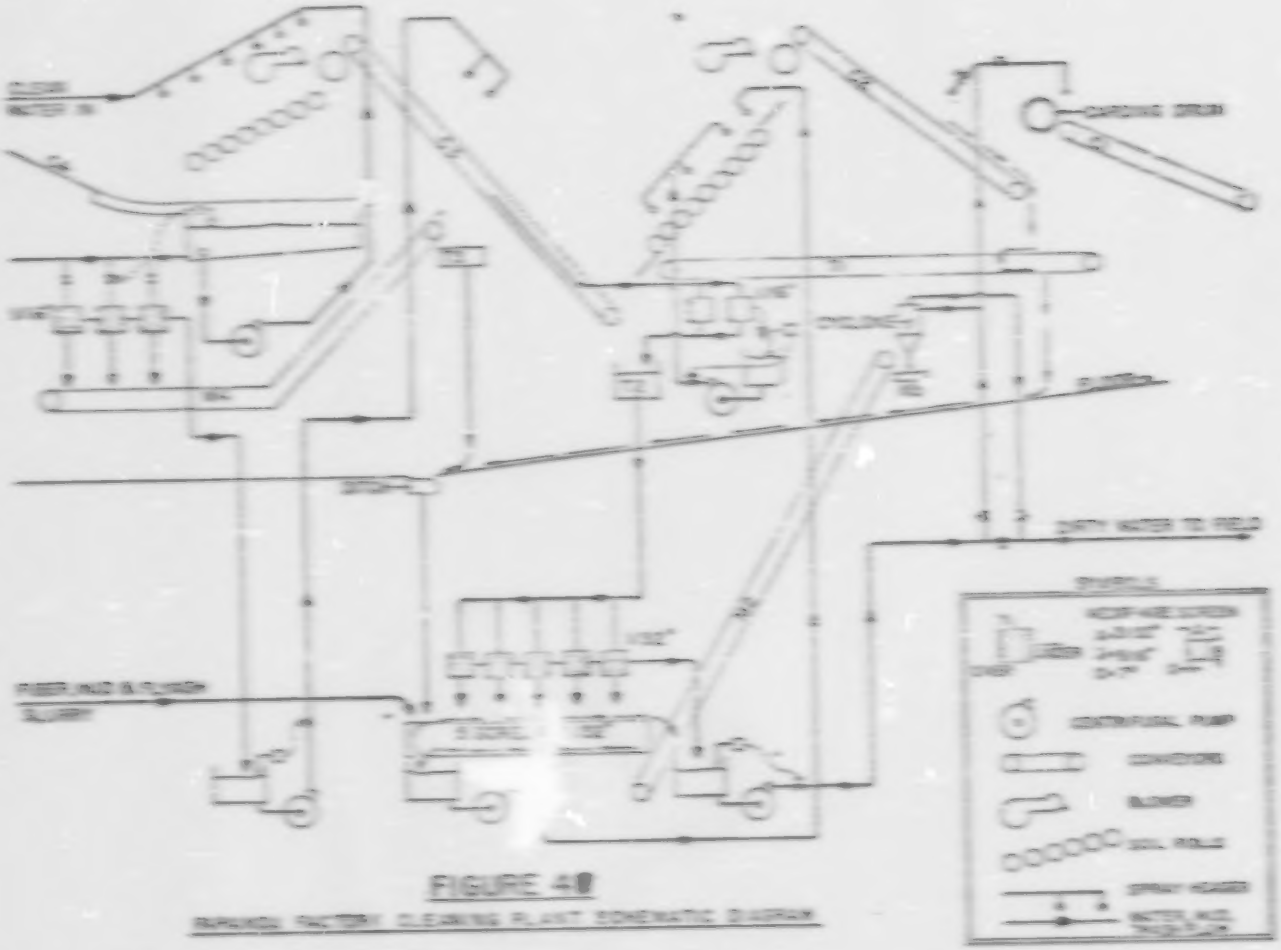


FIGURE 4B

RAMSEL FACTORY CLEANING PLANT SCHEMATIC DIAGRAM

at Papaikou (48-inch x 96-inch with a 30 degree apex angle) all connected in parallel. Their function is to remove soil particles in the range minus 0.36 to plus .003 inch from the dirty water being pumped to the fields.

As screens were being installed, an effort was made to determine the efficiency of the screens but because of the high variability of the wash water in soil and trash content as mentioned earlier, statistically reliable data were not easy to obtain. Typical values are listed in Table 20.

TABLE 20. ANALYSIS OF SCREENING EFFICIENCY

Date	Above Screen		Through Screen	
	% Solids	% Organic Matter	% Solids	% Organic Matter
Sept. 9, 1975	0.38	29.5	0.31	32.1
Sept. 15, 1975	0.59	27.4	0.56	30.5
Sept. 17, 1975	0.23	30.6	0.13	32.5
Sept. 24, 1976	0.26	39.0	0.24	38.2
	0.24	39.3	0.28	37.4
Sept. 25, 1975	0.59	33.7	0.44	38.5
	0.61	33.2	0.42	40.0
Sept. 26, 1976	0.30	34.8	0.32	43.3
	0.28	32.9	0.32	44.6
AVERAGE	0.39	33.4	0.32	37.5

Table 20 indicates that the screens reduced the solids loading by about eighteen percent and the relative percent of organic matter increased by about twelve percent after passing through the screens. The analyses were done in the same manner as previously described in the Water Analysis Section.

As this paper is going to press, tests are being run on the cyclones and mechanical changes are still being made to the cleaning plant.

SECTION 9

POWER PLANT

A high pressure (1250 psi) steam generation power plant was built with the expressed capability of burning fibrous waste material in addition to fuel oil.

The power plant is currently contracted by Hawaii Electric Light Company (HELCO) to supply 130,000 MWH annually, about 20% of the island's electrical needs, in addition to supplying the electric needs of HCPC.

Table 21 gives a breakdown of how the generating requirements are being met by the various fuels. Fibrous fuels include bagasse, wood chips, and macadamia nut shells, with bagasse comprising over 95% of these three items.

One of the major problems encountered so far has been with bagasse storage and the bagasse conveyor. Lack of adequate storage facilities occasionally means that trucks bringing bagasse from another mill (Wainaku) must be turned back, thus preventing utilization of this bagasse. The second major problem area has been with the bagasse conveyors which convey the bagasse from the storage area to the furnace. Major modifications were made during the 1975 off-season.

Another problem encountered has been with getting the proper fuel mixture. This is important because the BTU content of the various fuels varies, as does their moisture content. Thus, a proper mixture must be maintained in order to ensure proper furnace operation. To date, a complete solution to this complex problem has not been discovered.

The plant has the potential to supply more of its fuel needs from fibrous fuel that it currently is doing. It is hoped that with improvements in bagasse storage and conveying, this potential capability will be further realized.

TABLE 23. BTU DISTRIBUTION FROM POWER PLANT

Month	BTU Production			Total BTUs Produced	Total MWHrs Produced
	From Fuel Oil	From Bagasse	Other Waste Fuel		
	$\times 10^9$	$\times 10^9$		$\times 10^9$	$\times 10^3$
8/75	69.6	132.9	64.6	202.6	8.9
9/75	75.8	138.9	64.7	214.7	13.3
10/75	89.7	142.5	62.8	232.3	15.8
11/75	64.9	128.2	64.7	198.2	12.4
12/75	89.0	129.7	59.3	218.8	13.0
1/76	59.9	66.3	52.9	126.2	7.1
2/76	90.9	103.7	53.3	194.6	11.0
3/76	87.7	103.6	54.1	191.4	10.1

SECTION 10

CANE TRASH WET CLEANER

A considerable amount of potential fuel energy is lost each day in the form of cane trash. This trash is currently unusable because of the large amount of soil and moisture associated with it when it is removed from the cane cleaner.

To date, efforts to clean this trash to a degree necessary to utilize it as a fibrous fuel have not been feasible. The two main obstacles have been that the trash requires very heavy machinery for de-watering in order to burn well after washing and that the large amounts of water necessary for washing pose a disposal problem which has not yet been solved. The land disposal concept may provide the answer to this problem after the techniques for disposal of soil and water in full-scale commercial quantities have been adequately defined.

APPENDIX A

BOIL/ASH RATIO

Boil Type[a]	Boil Weight[b](g)	Ash Weight[c](g)	Boil/Ash
A	27,678	20,437	1.35
E	16,647	12,152	1.37
E	21,353	16,285	1.31
H	22,935	16,158	1.42
E	27,262	23,079	1.18
E	20,152	14,617	1.40
E	20,767	15,160	1.37
E	21,504	16,432	1.31
H	26,406	19,992	1.347
E	25,828	17,703	1.459
H	33,692	24,413	1.380
E	28,746	20,801	1.382
H	33,109	24,804	1.335
E	23,143	17,105	1.353
H	24,674	17,896	1.379
E	12,528	8,822	1.420
H	28,814	21,196	1.36
E	24,420	17,385	1.39
E	23,922	17,360	1.38
E	16,099	12,200	1.38
E	26,758	19,810	1.35
E	22,643	16,008	1.41
E	40,670	34,057	1.19
E	32,230	27,574	1.17
E	28,98	21.35	1.36
H	31.39	24.23	1.30
E	25.21	18.76	1.34
E	16.53	12.19	1.36
E	24.03	18.97	1.31
H	27.33	20.07	1.36
E	20.44	14.93	1.37
A	17,571	12,305	1.401
A	23,231	16,606	1.399
A	20,470	17,447	1.088
H	25,190	17,859	1.410
E	26,394	18,367	1.437
E	22,308	16,200	1.377
H	19,968	14,259	1.399

APPENDIX A (continued)

Soil Type[a]	Soil Weight[b](g)	Ash Weight[c](g)	Soil/Ash
K	20.347	14.168	1.43
K	18.856	3.093	1.41
H	20.578	14.943	1.37
K	23.067	18.285	1.27
K	20.560	15.130	1.35

[a] K = Kaiwiki, H = Hilo, A = Akaka
[b] Dried at 100° - 110°C
[c] Ashed at 500°C

APPENDIX B

INFILTRATION RATES

Test No.	Date	No. of Days Since Prev. Application	Line No.	No. of Prev. Applications To Line	Apparent Infiltration Rate (in./hr.)
1	7-15-75	0	1	0	1.5*
		0	3	0	1.7*
		0	5	0	0.8*
		0	7	0	1.9*
		0	11	0	1.5*
		0	13	0	2.1*
		0	15	0	0.4*
		5	17	0	1.3*
		0	21	0	1.3*
			Average		1.3, s.d.* 0.6
2	7-21-75	6	1	1	1.1
		6	3	1	3.2
		6	5	1	0.6
		6	7	1	1.5
		6	11	1	1.7
		6	13	1	1.1
			Average		1.4, s.d. 1.1
3	7-24-75	2	1	2	0.6
		0	2	0	2.4*
		2	3	2	0.8
		0	4	0	0.8*
		2	5	2	0.0
		0	6	0	2.1*
		2	7	2	0.0
		0	8	0	0.4*
		0	9	0	0.6*
		0	10	0	2.9*
		2	11	2	1.1
		0	12	0	0.8*
			Average		1.1, s.d. 0.9

APPENDIX B (continued)

Test No.	Date	No. of Days Since Prev. Application	Line No.	No. of Prev. Applications To Line	Apparent Infiltration Rate (in./hr)
4	7-24-75	1	1	1	0.4
		1	2	1	0.9
		1	3	1	0.9
		1	4	1	0.4
		1	5	1	0.0
		1	6	1	0.4
		1	7	1	0.6
		1	9	1	3.0
		1	10	1	1.28
		1	11	1	1.1
			Average		0.6, s.d. 0.4
5	7-25-75	2	8	1	0.0
		2	12	1	0.0
		4	13	2	0.6
		0	14	0	0.4*
		10	15	1	0.0
		10	17	1	0.4
		10	21	1	0.2
		0	23	0	0.0*
		0	25	0	2.1*
		0	27	0	6.3*
			Average		1.0, s.d. 2.0
6	7-28-75	3	8	2	0.0
		3	12	2	0.0
		3	13	3	0.9
		3	14	1	0.0
		3	17	2	0.4
		3	21	2	0.4
		3	23	1	0.0
		3	25	1	1.28
		3	27	1	1.71
			Average		0.5, s.d. 0.6
7	7-29-75	5	1	4	0.0
		5	2	2	0.0
		5	3	4	0.0
		5	4	2	0.6
		5	5	4	2.1
		5	6	2	0.6
		5	7	4	0.0
		5	9	2	1.1
		5	10	2	0.0
		5	11	4	0.0
			Average		0.4, s.d. 0.7

APPENDIX B (continued)

Test No.	Date	No. of Days Since Prev. Application	Line No.	No. of Prev. Applications To Line	Apparent Infiltration Rate (in./hr)
8	7-30-75	1	1	5	0.0
		1	2	3	0.0
		1	3	5	0.0
		1	4	3	0.4
		1	5	5	1.3
		1	6	3	0.8
		1	7	5	0.2
		1	9	3	0.4
		1	10	3	0.0
		1	11	5	0.2
			Average		0.3, s.d. 0.4

*Line never used previously
s = Standard Deviation

APPENDIX C

WATER ANALYSIS

Date	Location (Site #)	$ Salt in Sq. Mi.	# Inorganic Matter (# Solids in Sq. M.	Remarks
5-05-72*	1	1.26		Incoming water
		1.35		"
		1.39		
5-09-72*	2	0.23		Taken before osmotic treat
		0.23		" " " "
5-12-72*	2	0.25		
		0.25		
5-15-72*	2	0.30		
		0.30		
5-19-72*	2	0.29		
		0.29		
5-27-72*	2	0.42		
		0.42		
5-29-72*	2	0.61		
		0.60		
5-30-72*	2	0.41		
		0.39		
5-31-72*	2	0.29		
		0.28		
6-01-72*	3	0.35		
		0.35		Taken at head box
10-16-72*	4	0.305		Taken 150 ft. down ditch pipe trench
		0.305		Clear, fresh flowe water
10-17-72*	4	1.27		" " " "
		0.66		Taken at head box
		0.11		" " Trench 1, #1
		0.26		" " " 1, #4
		0.07		" " " 1, #8
		0.22		" " " 1, #12
		0.58		" " " 1, #16
				" " " 1, #22

APPENDIX C (continued)

Date	Location (Site #)	% Soil by Wt.	% Organic Matter of Solids by Wt.	Remarks
10-17-79*	1	1.20		Taken at Trench 1, #1
		1.34		" " " 1, #4
		1.39		" " " 1, #8
		1.48		" " " 1, #12
		1.46		" " " 1, #16
		1.48		" " " 1, #18
		1.39		" " " 1, #12, five hours after previous sample taken at same location
10-17-79*	1	1.25		Taken at Trench 1, #20
		1.23		" " " 1, #17
		1.23		" " " 1, #10
		1.11		" " " 1, #4
		1.26		" " " 1, #1
		1.27		" " " 1, #20
		1.28		" " " 1, #17
		1.33		" " " 1, #10
		1.30		" " " 1, #4
		1.26		" " " 1, #1
		1.28		" " " 1, #17
		1.28		" " " 1, #12
		1.30		" " " 1, #7
		1.27		" " " 1, #1
10-18-79*	1	1.21		break line
10-18-79*	1	1.29		Trench, flame water
		1.40		Taken at break line
		1.48		" " " Trench 7, #1, ventolin Beta 1420 Polymer
		1.53		" " " 7, #12, " " " "
		1.58		" " " 7, #22, " " " "
		1.56		" " " 7, #1, " " " "
		1.54		" " " 7, #12, " " " "
		1.53		" " " 7, #22, " " " "
		1.52		" " " 7, #1
		1.56		" " " 7, #12

EXHIBIT C (continued)

No.	Location Zone #	# Cells by Zn.	# Organic Matter in Cells by Zn.	Remarks
1-01-77*	A	1-10		Upper or Trench 1, #27
		1-07		" " " 1, #1 , contains Zone 1&2A Polymer
		1-13		" " " 1, #10, " " " "
		1-14		" " " 1, #20
		1-15		" " " 1, #1
		1-16		" " " 1, #20
		1-17		" " " 1, #27
1-01-77*	A	1-18		" " Level Two
		1-19		" " Trench 2, #2, Polymer Salem, #2075
		1-20		" " " 2, #4, " Salem, #2075
		1-21		" " " 2, #6, " Salem, #2075
		1-22		" " " 1, #2, " Dow A-23 Fertilizer
		1-23		" " " 1, #4, " Dow A-23 Fertilizer
		1-24		" " " 1, #6, " Dow A-23 Fertilizer
		1-25		" " " 2, #2, Control, No Polymer
		1-26		" " " 2, #4, Control, No Polymer
		1-27		" " " 2, #6, Control, No Polymer
		1-28		" " " 3, #2, " Salem, #2075
		1-29		" " " 3, #11, " Salem, #2075
		1-30		" " " 1, #2, " Dow A-23 Fertilizer
		1-31		" " " 1, #11, " Dow A-23 Fertilizer
		1-32		" " " 2, #2, Control, No Polymer
		1-33		" " " 2, #11, Control, No Polymer
		1-34		" " " 3, #2, " Salem, #2075
		1-35		" " " 3, #4, " Salem, #2075
		1-36		" " " 3, #6, " Salem, #2075
		1-37		" " " 1, #2, " Dow A-23 Fertilizer
		1-38		" " " 1, #4, " Dow A-23 Fertilizer
		1-39		" " " 1, #6, " Dow A-23 Fertilizer
		1-40		" " " 2, #2, Control, No Polymer
		1-41		" " " 2, #4, Control, No Polymer
		1-42		" " " 2, #6, Control, No Polymer
		1-43		" " Level Two

APPENDIX C (continued)

Date	Location (Site #)	% Soil By Wt.	% Organic Matter of Solids By Wt.	Remarks
11-04-75*	4	0.25		Taken at Trench B, #2, Polymer Salem, 85275
		0.18		" " " B, #10, " Salem, 85275
		0.24		" " " C, #2, " Dow A-23 Fertilizer
		0.21		" " " C, #10, " Dow A-23 Fertilizer
		0.53		" " " D, #2, Control, No Polymer
		0.24		" " " D, #10, Control, No Polymer
		0.23		" " " B, #2, " Salem, 85275
		0.21		" " " C, #2, " Dow A-23 Fertilizer
		0.18		" " " D, #2, Control, No Polymer
11-05-75*	4	0.34		T.A. Sta. 2 **
		0.33		T.A. Sta. 9
		0.17		T.B. Sta. 1
		0.33		T.B. Sta. 6
		0.35		T.B. Sta. 11
		0.54		T.C. Sta. 1
		0.29		T.C. Sta. 6
		0.31		T.C. Sta. 11
		0.24		T.D. Sta. 2
		0.32		T.D. Sta. 9
		0.31		T.A. Sta. 2
		0.32		T.A. Sta. 9
		0.30		T.B. Sta. 1
		0.29		T.B. Sta. 6
		0.32		T.B. Sta. 11
		0.29		T.C. Sta. 1
		0.29		T.C. Sta. 6
		0.31		T.C. Sta. 11
		0.31		T.D. Sta. 2
		0.31		T.D. Sta. 9
		0.89		Head box
		1.00		Head box
11-11-75*	4	0.25		T.B. Sta. 1
		0.17		T.B. Sta. 2

APPENDIX C (continued)

Date	Location (Site #)	% Soil By Wt.	% Organic Matter Of Solids By Wt.	Remarks
11-11-75*	4	0.12		T.B. Sta. 11
		0.13		T.C. Sta. 1
		[illegible]		T.C. Sta. 8
		0.13		T.C. Sta. 11
		0.15		T.D. Sta. 4
		0.12		T.D. Sta. 8
		0.17		T.D. Sta. 11
		0.04		T.B. Sta. 1
		0.05		T.B. Sta. 8
		0.06		T.B. Sta. 11
		0.02		T.C. Sta. 1
		0.07		T.C. Sta. 8
		0.06		T.C. Sta. 11
		0.04		T.D. Sta. 1
		0.06		T.D. Sta. 8
		0.06		T.D. Sta. 11
		3.65	17.92	
11-12-75*	4	0.26		T.B. Sta. 4
		0.18		T.B. Sta. 11
		0.20		T.B. (Slipknot)
		6.69		T.C. Sta. 4
		0.21		T.C. Sta. 11
		0.21		T.C. (Slipknot)
		0.24		T.D. Sta. 4
		0.19		T.D. Sta. 11
		0.19		T.D. (Slipknot)
		3.51	18.92	Head box
		3.30	15.67	Head box
		3.21	19.89	Flume Opening
		3.16	20.29	Flume Opening
11-13-75*	4	3.54		T.B. Sta. 4
		0.21		T.B. Sta. 11
		0.22		T.B. End Slipknot

APPENDIX C (continued)

Date	Location (Site #)	% Soil By Wt.	% Organic Matter Of Solids By Wt.	Remarks
11-13-75*	4	8.76		T.C. Sta. 4
		0.20		T.C. Sta. 11
		0.22		T.C. Siphon
		0.18		T.B. Sta. 4
		0.21		T.B. Sta. 11
		0.22		T.B. Siphon
		0.22		T.B. Siphon (slow flow)
12-01-75*	4	0.20		T.C. #11
		0.22		T.C. Siphon Exit
		4.26		Head box
		2.72		Flume Opening
		0.11		T.B. #7
		0.20		T.B. #11
		0.15		T.B. Siphon
		1.99		T.C. #7
		0.15		T.C. #11
		0.24		T.C. Siphon Exit
		2.75		Head box
		2.94		Flume Opening
		0.20		T.B. #7
		0.22		T.B. #11
		0.18		T.B. Siphon
		1.69		T.C. #7
12-15-75*				
	4	4.70		Flume Opening
		3.49		T.A. Mid
		1.95		T.A. End
		3.60		T.B. Mid
		0.70		T.B. End
		4.26		T.C. Mid
		2.57		T.C. End
		0.20		T.D. Mid
		0.23		T.D. End

APPENDIX C (continued)

Date	Location (Site #)	% Soil By Wt.	% Organic Matter Of Solids By Wt.	Remarks
12-15-75*	4	0.22		T.F. Mid
		0.21		T.F. End
		4.12		T.F. Mid
		2.05		T.F. End
		0.18		T.G. Mid
		0.19		T.G. End
		0.20		T.E. Mid
		0.20		T.E. End
		0.17		T.I. Mid
		0.18		T.I. End
		0.24		T.J. Mid
		0.20		T.J. End
12-18-75*	4	5.05		
		5.05		
2-03-76*	5A	1.36	19.86	Taken at 6" intake pipe to screens from dry cleaner
		1.43	20.18	Taken under 1/64" screen
		0.18	89.34	Taken at end of a trench
		2.83	13.94	Taken at 6" intake pipe to screens from dry cleaner
		2.16	13.91	Taken under screen
		0.15	78.42	Taken from siphon
		0.18	92.39	" " "
		0.15	91.49	" " "
		0.17	93.72	
2-13-76*	5A	2.79	14.20	Taken from water which went over the 1/64" screen not through it
		2.31	15.10	Taken from water which went through 1/64" screen
		.69	19.60	Taken from water which went over the 1/64" screen not through it
		2.32	15.90	Taken from water which went through 1/64" screen

** means Trench A, at second board from beginning of trench (see Tables 16, 17).
* Passed through 1.6mm screen at dry cleaner
+ Passed through 0.4mm screen at dry cleaner or field

APPENDIX D

RAINFALL RECORD FOR TEST SITE

DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
8/01/75		9/08/75	0.25
8/02	0.57	9/09	0.25
8/03	0.86	9/10	0.02
8/04	0.92	9/11	0.00
8/05	0.10	9/12	0.00
8/06	0.03	9/13	0.00
8/07	0.00	9/14	0.00
8/08	0.00	9/15	0.10
8/09	0.19	9/16	0.65
8/10	0.08	9/17	0.33
8/11	0.34	9/18	
8/12	0.22	9/19	
8/13	0.15	9/20	0.00
8/14	0.53	9/21	0.01
8/15	0.10	9/22	0.05
8/16	0.05	9/23	0.07
8/17	1.20	9/24	0.03
8/18	0.20	9/25	0.26
8/19		9/26	0.31
8/20		9/27	0.06
8/21		9/28	0.20
8/22		9/29	0.05
8/23		9/30	0.00
8/24		10/01	0.00
8/25		10/02	0.00
8/26	0.02	10/03	0.21
8/27	0.17	10/04	0.05
8/28	0.53	10/05	0.20
8/29	0.07	10/06	0.25
8/30		10/07	0.53
8/31		10/08	0.37
9/01		10/09	0.68
9/02		10/10	0.00
9/03	0.00	10/11	0.03
9/04	0.00	10/12	0.06
9/05	0.00	10/13	0.00
9/06	0.00	10/14	0.05
9/07	0.15	10/15	0.68

APPENDIX D (continued)

DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
10/16/75	0.02	12/02/75	0.02
10/17	0.78	12/03	6.90
10/18	0.33	12/04	3.18
10/19	1.37	12/05	0.02
10/20	0.37	12/06	0.00
10/21	0.15	12/07	0.20
10/22	0.00	12/08	0.00
10/23		12/09	0.00
10/24		12/10	0.05
10/25		12/11	0.00
10/26		12/12	0.00
10/27		12/13	0.27
10/28		12/14	0.49
10/29	0.12	12/15	0.72
10/30	0.00	12/16	0.12
10/31	0.35	12/17	0.24
11/01	0.05	12/18	0.00
11/02	0.00	12/19	0.00
11/03	0.00	12/20	0.00
11/04	0.00	12/21	0.00
11/05	0.10	12/22	0.00
11/06	0.00	12/23	0.00
11/07	0.04	12/24	0.00
11/08	0.26	12/25	0.00
11/09	0.46	12/26	0.00
11/10	0.40	12/27	0.00
11/11	0.17	12/28	0.72
11/12	0.30	12/29	0.00
11/13	0.00	12/30	0.00
11/14	0.00	12/31	0.05
11/15	0.00	1/01/76	0.80
11/16	0.23	1/02	0.45
11/17	0.58	1/03	1.05
11/18	0.00	1/04	0.40
11/19	0.00	1/05	3.70
11/20	5.06	1/06	0.63
11/21		1/07	4.42
11/22		1/08	1.01
11/23		1/09	0.16
11/24		1/10	0.65
11/25		1/11	0.00
11/26		1/12	0.70
11/27		1/13	1.00
11/28		1/14	0.25
11/29		1/15	0.00
11/30		1/16	0.10
12/01		1/17	0.70

APPENDIX D (continued)

DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
1/18/76	0.00	3/09/76	1.11
1/19	0.10	3/06	0.00
1/20	0.06	3/07	1.04
1/21	0.48	3/08	0.23
1/22	1.14	3/09	1.04
1/23	0.05	3/10	3.08
1/24	0.00	3/11	0.01
1/25	0.00	3/12	0.44
1/26	0.00	3/13	0.12
1/27	0.00	3/14	0.00
1/28	0.00	3/15	0.00
1/29	1.66	3/16	0.01
1/30	0.00	3/17	1.07
1/31	0.00	3/18	0.44
2/01	0.00	3/19	0.00
2/02	0.00	3/20	0.29
2/03	0.00	3/21	0.08
2/04	0.00	3/22	0.16
2/05	0.07	3/23	0.50
2/06	0.00	3/24	0.22
2/07	0.04	3/25	0.12
2/08	0.29	3/26	1.13
2/09	0.24	3/27	1.26
2/10	0.07	3/28	0.84
2/11	0.11	3/29	0.44
2/12	0.03	3/30	0.91
2/13	0.11	3/31	1.54
2/14	0.72	4/01	1.11
2/15	1.06	4/02	0.00
2/16	2.42	4/03	0.28
2/17	0.11	4/04	0.52
2/18	0.20	4/05	0.58
2/19	0.12	4/06	0.02
2/20	0.07	4/07	0.00
2/21	0.52	4/08	0.00
2/22	0.17	4/09	0.15
2/23	1.58	4/10	0.27
2/24	1.15	4/11	0.06
2/25	0.00	4/12	0.35
2/26	1.38	4/13	0.17
2/27	0.56	4/14	0.02
2/28	0.01	4/15	0.04
2/29	0.13	4/16	0.12
3/01	0.04	4/17	0.54
3/02	0.00	4/18	0.07
3/03	1.97	4/19	0.51
3/04	0.53	4/20	0.74

APPENDIX D (continued)

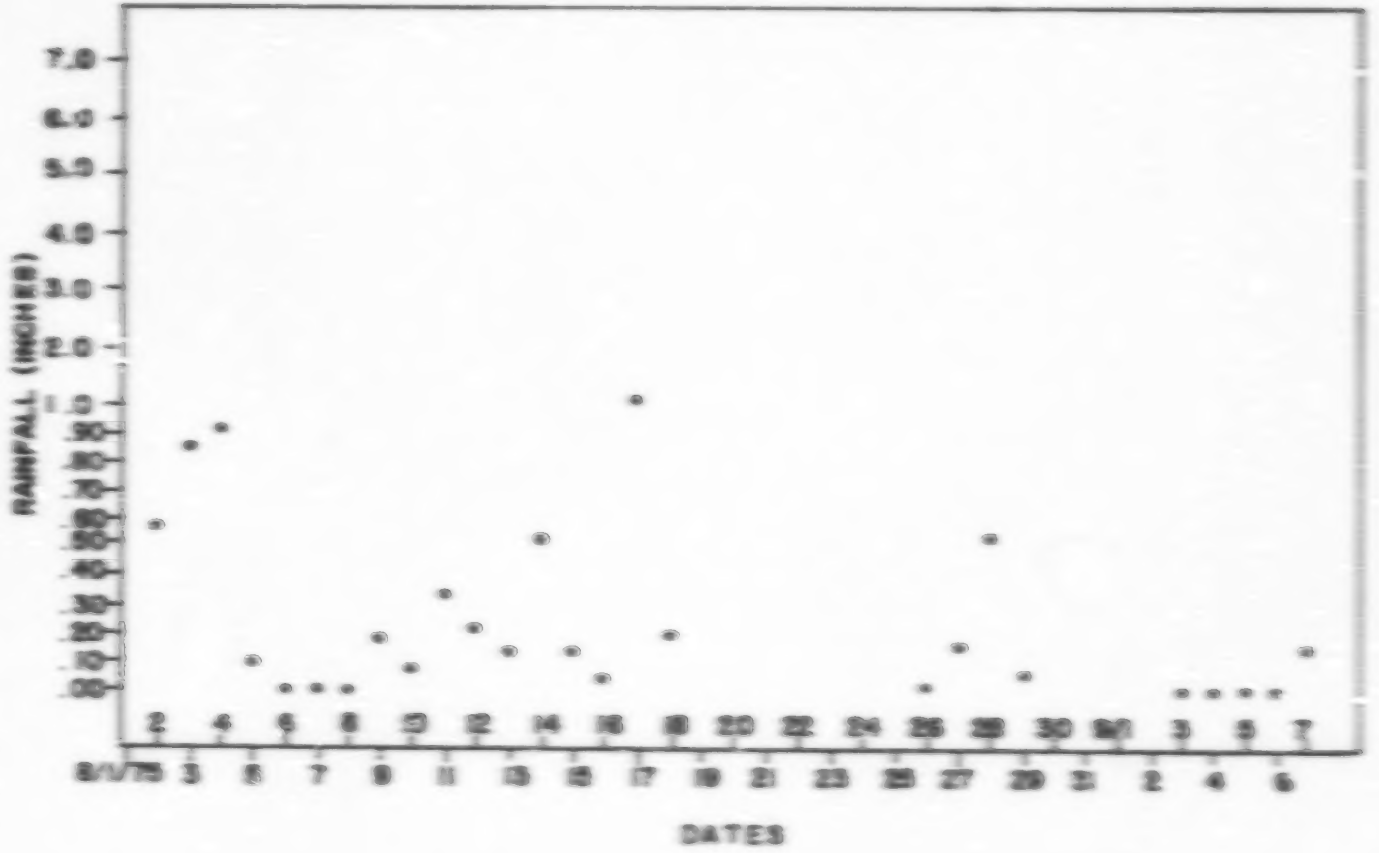
DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
4/21/76	0.15	6/07/76	0.05
4/22	0.72	6/08	0.29
4/23	0.33	6/09	0.01
4/24	0.28	6/10	0.06
4/25	0.02	6/11	0.00
4/26	0.30	6/12	0.03
4/27	0.14	6/13	0.00
4/28	0.00	6/14	0.00
4/29	0.00	6/15	
4/30	1.24	6/16	
5/01	0.47	6/17	0.22
5/02	0.09	6/18	0.29
5/03	0.34	6/19	0.08
5/04	0.17	6/20	0.33
5/05	0.00	6/21	0.09
5/06	0.02	6/22	
5/07	0.07	6/23	0.00
5/08	0.02	6/24	0.27
5/09	0.00	6/25	0.04
5/10	0.02	6/26	0.19
5/11	0.09	6/27	0.26
5/12	0.03	6/28	0.11
5/13	0.14	6/29	0.11
5/14	0.01	6/30	0.22
5/15	0.00	7/01	0.09
5/16	0.00	7/02	0.08
5/17	0.10	7/03	0.22
5/18	0.01	7/04	0.25
5/19	0.15	7/05	0.00
5/20	0.31	7/06	0.04
5/21	0.24	7/07	0.31
5/22	0.37	7/08	0.98
5/23	0.34	7/09	0.16
5/24	0.15	7/10	0.09
5/25	0.03	7/11	0.00
5/26	0.19	7/12	0.10
5/27	0.30	7/13	0.00
5/28	0.15	7/14	0.00
5/29	0.18	7/15	0.00
5/30	0.27	7/16	0.30
5/31	0.02	7/17	0.00
6/01	0.27	7/18	0.13
6/02	0.00	7/19	0.00
6/03	0.00	7/20	0.07
6/04	0.00	7/21	0.42
6/05	0.00	7/22	0.02
6/06	0.00	7/23	0.01

APPENDIX D (continued)

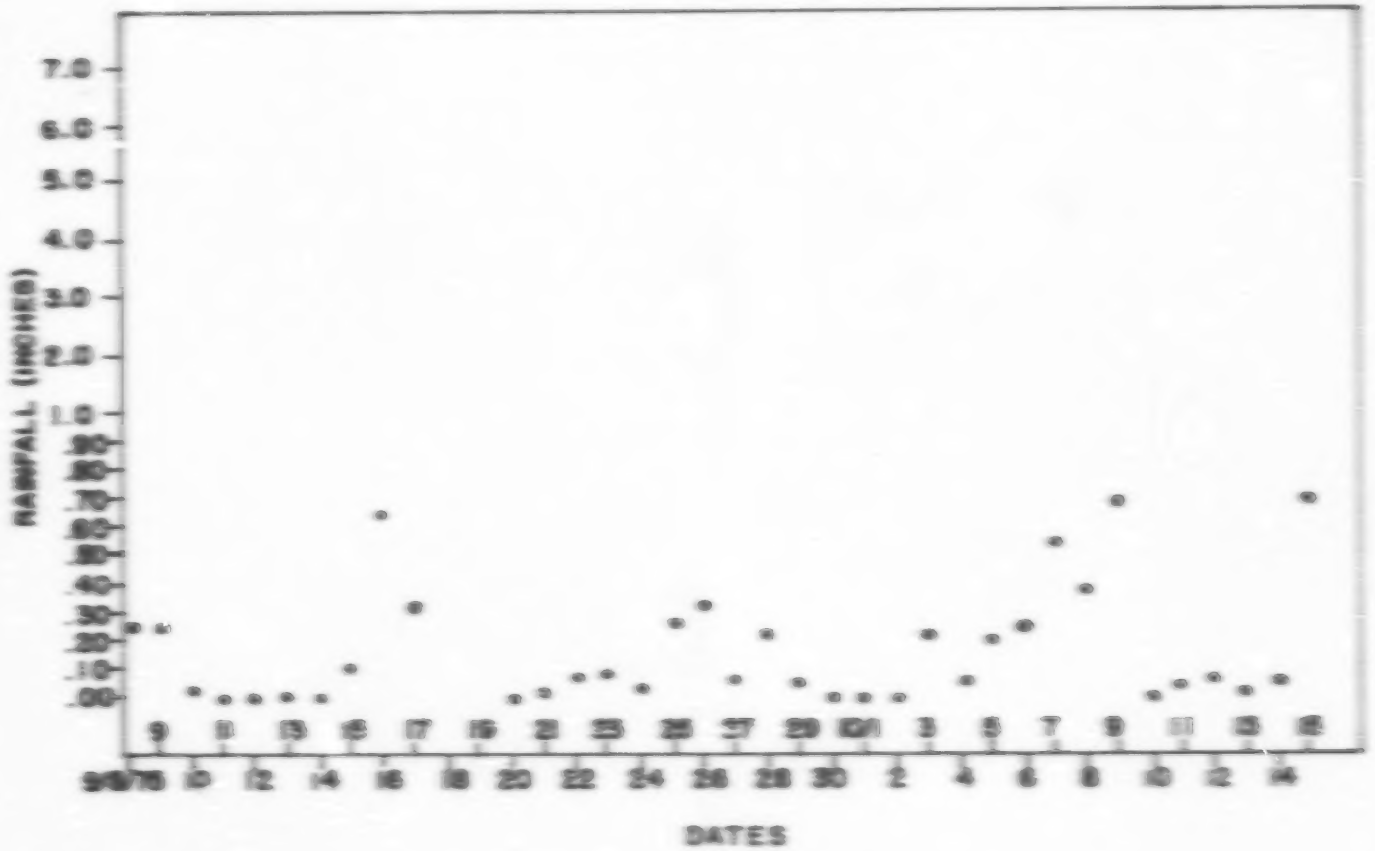
DATE	RAINFALL (in.)
7/24/76	0.74
7/25	0.52
7/26	0.02
7/27	0.30
7/28	0.08
7/29	0.00
7/30	0.02
7/31	0.03
8/01	0.04
8/02	0.16

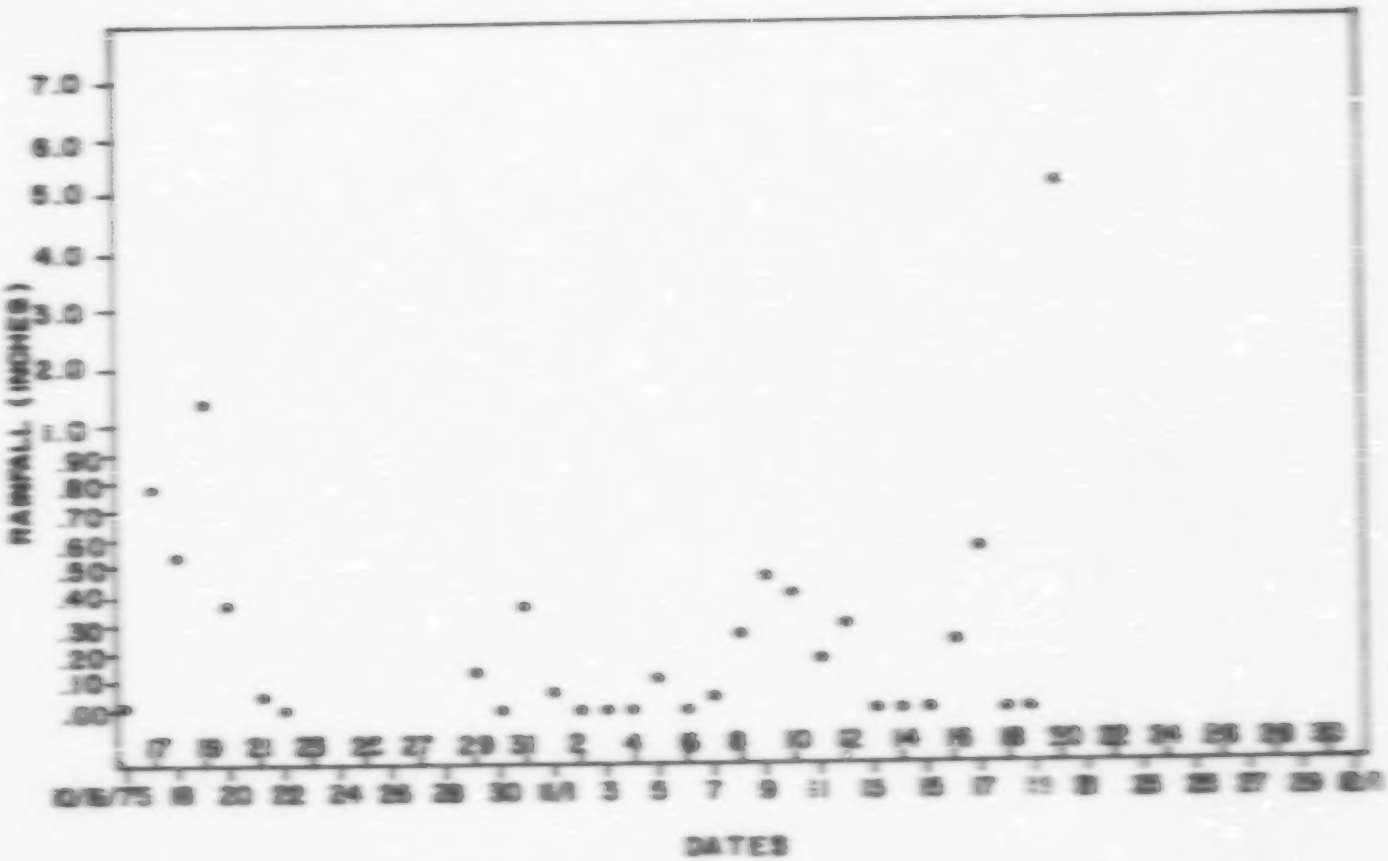
APPENDIX I

RAINFALL RECORD AT TEST SITE. GRAPHICAL PRESENTATION



APPENDIX E (continued)



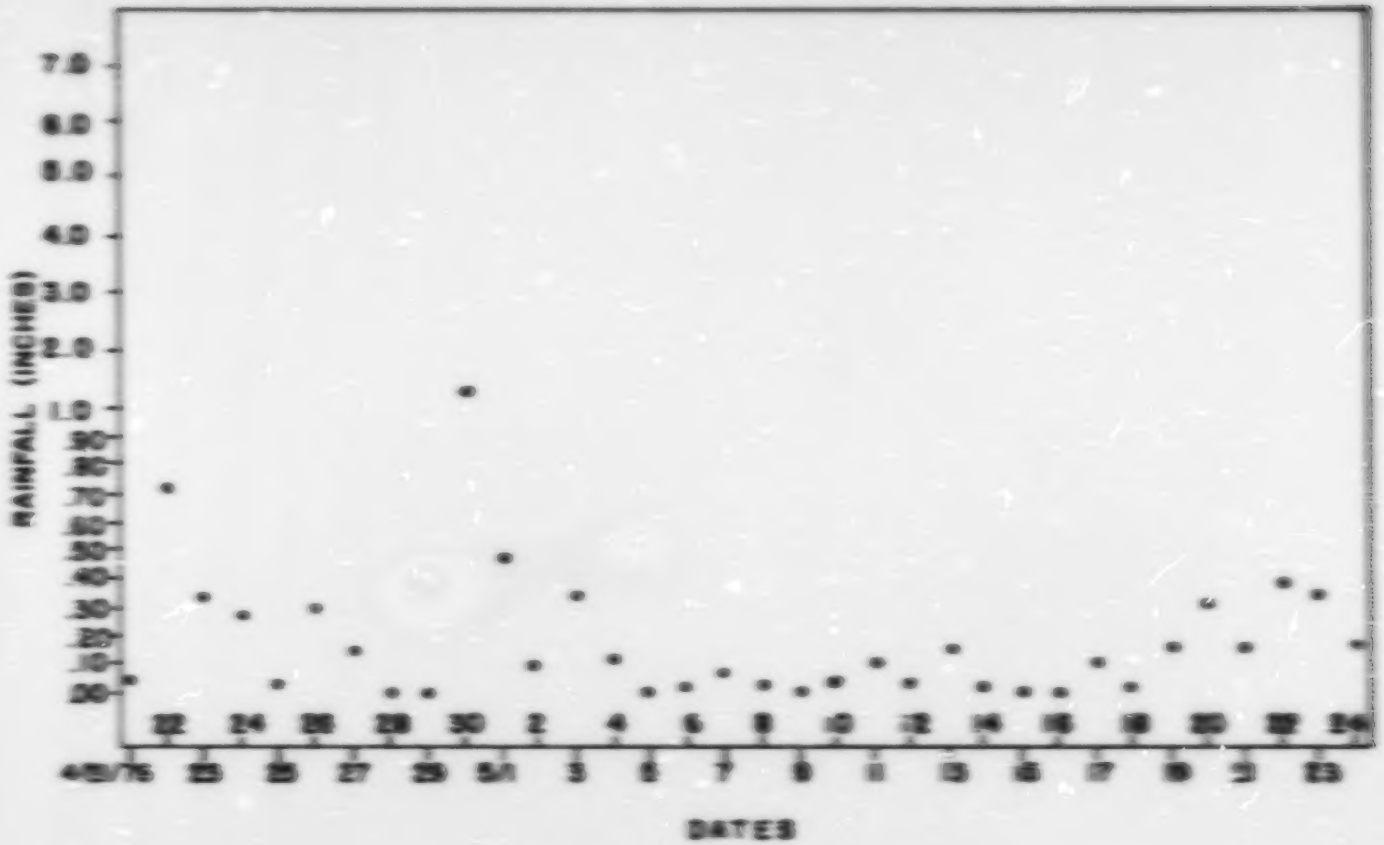

RAINFALL (INCHES)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
.90
.80
.70
.60
.50
.40
.30
.20
.10
.00
DATES

RAINFALL (INCHES)
DATES

RAINFALL (INCHES)

RAINFALL (INCHES)
DATES

APPENDIX E (continued)



RAINFALL (INCHES)
DATES

RAINFALL (INCHES)